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PROCEEDINGS AND INDEX

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No. 1

PROCEEDINGS

THE BICENTENARY OF THE BIRTH OF RICHARD ARKWRIGHT

In December, 1732, there was born at Preston one who, in the opinion of many, is the most remarkable figure in the history of cotton textiles—Richard Arkwright. The recognition of the bicentenary of his birth being particularly apposite it is noteworthy that the Newcomen Society invited Mr. Frank Nasmith (Fellow and Honorary Secretary of the Institute) to deliver a lecture to the Society on 14th December 1932, at the Science Museum, South Kensington. The text of that lecture appears below. It is to be noted also that the Municipal Authorities of Preston have invited the same lecturer to address a celebratory meeting to be held early in February this year.

RICHARD ARKWRIGHT

By FRANK NASMITH

Complete and correct appreciation of Arkwright's remarkable influence on the development of the factory system in the cotton industry can only be obtained by a full understanding of the conditions which prevailed when he commenced to take an interest in cotton spinning, and of the processes through which cotton passes from its raw state to the finished product. In this brief survey of the real lasting work of his life, apart from the question of his inventions, it is proposed to stress what may be considered his greater usefulness, namely, the ordering of those processes which constitute even to-day the method and practice of cotton spinning. It is not necessary to enumerate here the processes through which cotton passes to-day, and attention may be drawn at once to the conditions prevailing in the industry in his time.

Only a very few years before his birth it was little different from what it had always been, employing manual labour aided by crude appliances—a domestic industry in every sense. True, there had been definite efforts to collect together the weavers and get them to work for certain merchants, and to this extent there was appreciation of the necessity for organised effort to meet demand.

In the year 1733 John Kay invented his fly shuttle. It will not be necessary to detail the advantages of this invention. It will suffice to say that it revolutionised the weaving industry and made it absolutely imperative that improved methods of spinning be found to cope with the increasing demand for warp and soft yarn.

Inventions quickly followed. In 1738 Paul's "Spinning by Rollers" came out, and in 1748 the same inventor's Carding engine was introduced. It should be appreciated that the insistent demand for more and more yarn to feed the improved hand looms of those days brought into being an increasing number of spinners all agog to secure to themselves anything that would facilitate the easy production of yarn. Arkwright grew up in a world crying out for new ideas and

the perfecting of the inventions recently introduced. The time was ripe for great development. Engineering knowledge was growing apace. There was a market for the right kind of idea and Arkwright was the man who, more than any other, had vision to see and energy to consummate.

Environment has a great bearing on the character and outlook of man. In the case of Arkwright it had - in my opinion - everything to do with his emergence from obscurity as an itinerant barber to prominence as the first master cotton spinner of Great Britain, or even, at that period, of the world. Arkwright was the youngest child of a somewhat large family, which was in poor circumstances. He had very little schooling, a deficiency which in later life he strenuously endeavoured to remedy. He was apprenticed to one Nicholson, a barber of Preston, or it may have been Kirkham, some seven or eight miles outside Preston. Having completed his due term with Nicholson he migrated to Bolton-le-Moors, or Bolton as it is known to-day. Now in those days the town and district of Bolton was noted for its activity in cotton manufacture, and Arkwright must have been in daily contact with the trade, and, it is reasonable to suppose, alive to the development that was taking place. His very vocation of barber must have brought him into close contact with many men engaged in the industry, and from them he must have acquired a considerable amount of information which was so ably utilised by him at a later date. Another pointer towards Arkwright's interest in or connection with the cotton industry is indicated by Seymour Jones who states that five of Arkwright's sisters married men more or less connected with the cotton industry.

In a locality absorbed in cotton manufacture, Arkwright could not fail to become saturated with facts relating to the developing industry. One of the main topics of conversation would be the possibilities offered by the changes taking place and the improved machines being introduced. It is stated of him that he was of an inquisitive nature. This we can fully believe, and there can be little doubt that before he dropped his barbering and took up what became the chief work of his life he was storing up a well ordered and arranged set of facts which he put to most excellent use later. His early training could not have given him that complete spinning sense which in later life he proved he possessed so fully. He was never trained in the art of spinning, yet, in my opinion, he had a truer sense of what was required to secure the transformation of a mass of tangled fibres into a regular thread of yarn by machinery than any of the other inventors of his time, nearly all of whom had been brought up in close contact with the trade.

He settled in Bolton, probably in 1750, when he was a young man of 18, and married for the first time on the 31st March 1755. There is no authentic record with reference to the death of his first wife, but we do know he married for his second wife Margaret Biggins of Pennington. It was this wife from whom he was separated owing to a dispute which will be referred to later. It had been said that Arkwright was induced to enter cotton spinning owing to the gradual disuse of wigs and consequent reduction of his income. In view of the dominant personality he expressed in many striking ways throughout his life, it would be much more reasonable to assume that he had very carefully weighed up the whole situation and had come to the conclusion that there were going to be immediate and enormous developments in the cotton manufacturing industry, that someone was going to make quite a lot of money out of the trade and that he might as well enter it and secure his share. By the time he made his move I am fully convinced that he had acquired a considerable knowledge and that in one sense at least and in one department he had become a highly educated man. He knew what was going on and he knew sufficient of the means and methods available to start right. The conclusion that it is desired should be drawn is that Arkwright was not an uncultured barber when he adventured forth into the cotton industry. In my opinion he was an astute individual who had natural ability to acquire knowledge from hearsay, to carefully analyse the information that came his way, and to apply it practically.

It is not material to us in dealing with the status of Arkwright whether Paul or Wyatt was the original inventor of the system of spinning by rollers. It is sufficient that in the Specification of 1738 in the name of Paul and numbered 562, a statement is made which indicates clearly that the idea of employing "a succession of other rollers, cylinders, or cones moving proportionally faster than the first draw the rope thread or sliver into any degree of fineness which may be required." Undoubtedly here we have the germ idea of drafting, or reducing the number of fibres in the cross section by means of a number of pairs of rollers each succeeding pair travelling at a higher rate of speed than those preceding them.

Between Paul's first patent and his second, Daniel Bourn in 1748 took out Patent 628, describing a method of mounting cards upon cylinders or rollers "and that these act against each other by a circular motion and that they may be moved either by hand or by a water wheel." Later he states "the cards are wrapped round the cylinders which by their circular motion, and at the same time their acting upon one another, card the wool or cotton sufficiently fine for spinning." Surely here we have the forerunner of the roller and clearer card of a much later date.

Bourn also appreciates the necessity for even distribution of the material over the face of the card which is referred to in Paul's Specification of his Patent 636 of 1748. In this particular specification he refers to a method of taking off the material by means of a "stick with needles in it."

We now come to Paul's Patent 724 of 1758 in which he refers specially to "a pair of rollers." In the available illustrations of Paul's machine only one pair of rollers are shown and it would appear that he—or Wyatt—had not been able to perfect the method outlined in his earlier Patent of drafting by rollers and at the same time spinning a yarn. In this specification he describes his method of producing his thread as follows. "The several rows which being put between a pair of rollers or cylinders, is by their turning round delivered to the nose of a spindle, in such proportion to the thread made as is proper for the particular occasions. From hence it is delivered to a bobbin, spole or quill, which turns upon the spindle and which gathers up the thread or yarn as it is spun. The spindle is so contrived as to draw faster than the rollers or cylinders give in proportion to the length of thread or yarn into which the matter to be spun is proposed to be drawn." From this we learn that Paul relied on the difference in the delivery speed of his single pair of rollers and the speed of his spinning spindle to secure that drafting or attenuation which he suggested in his first Patent should be secured by a succession of rollers running at increasing rates of speed. It would appear from this that he had discarded entirely the roller method for some reason which is not very evident. A much more significant fact emerges, however, namely, that he anticipated the method of drafting and spinning—or perhaps we might say in this particular twisting—which was subsequently adopted in part in the Mule. In both cases the delivery of roving is retarded and the twisting thread is passed to the nose of a spindle and by this means a certain amount of drafting is secured. It should be appreciated that this method of attenuation is not so perfect or complete as that secured by means of a number of pairs of rollers. It is useful and in mule spinning to-day imparts a fine evening up of the fibres which makes a mule spun yarn so much more regular than a ring spun yarn, but it is not comparable as stated with the results secured from drafting by rollers. This is a point which needs emphasis, because on it depends to a certain extent our judgment of the position of Arkwright as an inventor.

The next Patent granted was that to Richard Arkwright in 1769, the number being 931. In the Specification Arkwright distinctly refers to four pairs of rollers. Further he goes on to state "That part of the roller which the cotton runs through is covered with wood the top roller with leather and the bottom one fluted, which lets the cotton through it and by one pair of rollers moving quicker than the

other, draws it finer for spinning." Then he refers to the flyers and the method of building up the yarn package. His method of winding on was somewhat crude. This Patent ran its full term and was never challenged. That is for 14 years Arkwright enjoyed the advantages and profits of his spinning machine which, as is no doubt well known, was called a water frame because water power was subsequently employed to drive it. Although Paul did describe the use of rollers he apparently did not bring such use to perfection, because it was only at a much later date, about 1781, that on the Patent records being searched the fact was discovered that in his earlier specification the method was described. Arkwright appreciated the necessity of covering his top rollers with leather, a practice that obtains to this day, and on the small roller stand which appears in one picture of him, this method of clothing such rollers is clearly indicated.

In 1770 Hargreaves patented his spinning jenny, the number of the Specification being 962. It is a matter of controversy as to when Hargreaves invented his machine, but the weight of opinion appears to indicate the year 1764, the device being perfected by 1767, both dates preceding the year of Arkwright's Patent. Even so it hardly concerns Arkwright's claim to be a capable inventor because Hargreaves did not use rollers for effecting the attenuation of the sliver or untwisted ropes of fibres. We are, therefore, not materially concerned with Hargreaves and can pass on to Arkwright's next Patent, namely, No. 1111 of 1775, which in principle describes a means for Carding Cotton. It, in fact, contains a good deal more than the simple mechanism for that purpose. It is a very bad example of a Specification which undoubtedly should have been rendered invalid apart altogether from reason of infringement. The specification is ambiguous and apparently a distinct attempt to camouflage the true issue. If inventors had been compelled to attach claims to their specifications in those days Arkwright would have been put to some trouble to draft a set that would have been a true reflection of what he described. While certain of the elements described and illustrated can be termed complementary, surely no one would expect to find in a specification describing a carding engine a "beater or breaker of seeds, husks, etc., and a finer of the flax, hemp, and other articles which are prepared for dressing, in which *a* is a wheel with teeth, which by acting upon a lever raises the hammer *c*, the lever being movable upon the centre *d*." The comb operated by a crank is new so far as previous specifications of Patents go, and in a refined and modified form is used to-day on all carding engines. Then we have twisting mechanism including the driving of a spindle bobbin and flyer which, although essential to the process of thread production as then known, need not have been included, unless Arkwright was following the custom of putting some twist into his sliver in a similar manner to the way slubbing is made to-day. It may be that Arkwright was clouding the issue.

What inventions then can we accredit to Arkwright? Use of rollers had been described by Paul, therefore he was not the originator of the idea. The flyer was many years old, and the method of driving a number of spindles collectively not new. Considerable time elapsed before Arkwright perfected his first machine, therefore as Baines says "he did not receive from any other person a perfect machine." On all the evidence we have before us we must award to Arkwright the honour of producing a machine in which the untwisted rope of sliver was attenuated by pairs of rollers running at different speeds, the covering of the top rollers of a pair with leather, and fluting the lower ones, and twisting or spinning the fibres issuing from the rollers into a thread. If he did this alone then much honour and praise must be accorded to him because he had devised the first practicable machine for spinning.

The celebrated Case had really no concern with the spinning machine patent, although through ignorance or intent its details were dragged in perhaps with a view to discredit Arkwright. The fact that Arkwright's first patent was never attacked through the 14 years of its life is some proof of the validity of his claim.

The celebrated Case was the cause of much controversy over a number of years and considerable partisanship was evidenced. Highs, the reel maker, was engaged by Arkwright and undoubtedly worked with him at perfecting his devices. It was quite a natural thing for Arkwright, who was no engineer, to engage a skilled man, but in my opinion it was Arkwright who directed the efforts of Highs throughout. The crank and comb were claimed by Arkwright, and there is every reason to believe that he really invented them. Baines states that he came to the opinion owing to the evidence raised at the trial that James Hargreaves invented them, and this opinion was backed by the fact that Arkwright offered no disproof at the time. Subsequently Baines received important testimony in Arkwright's favour from the son of Mr. James, the partner of Hargreaves. It was averred that "He (James Hargreaves) was not the inventor of the crank and comb. We had a pattern chalked out upon a table by one of the Lancashire men in the employ of Arkwright; and I went to a frame-smith of the name of Young to have one made. Of this Mr. Arkwright was continually complaining and it occasioned some angry feelings between the parties." So we must accord the invention of the crank and comb to Arkwright. Further evidence was prepared by Arkwright on applying for a new trial in which he set out to disprove the evidence of Eliza beth and George Hargreaves.

* Arkwright, as is well known, lost his case, but, as emphasised by Mr. Seymour Jones, although he did so "The principles involved therein" (referring to the Carding Engine) "remain with us though detailed improvements have been introduced as the result of general experience."

Although Arkwright cannot perhaps be regarded as a true and first inventor, he can be given great credit for perfecting and bringing into commercially practicable shape many ideas that had been, directly or indirectly communicated to him. He must at the same time be considered the inventor of a number of auxiliary attachments, accessories, and methods of construction which translated the practice of spinning cotton from a manual to a machine operation.

We now come to the most important phase of Arkwright's life, during which his great activities in establishing the newly mechanised cotton industry on a sound basis were exercised to the full. Investigations indicate that there were two camps, one for and the other against Arkwright. To the one he was a rogue and a robber, nothing he ever did was of real value and certainly not original, while to the adherents of the other camp he was an inventive genius and a man of dominant personality. Even Baines, who holds the balance very evenly, will not attribute the credit of starting the factory system to Arkwright. He instances the silk mills that were already in existence in 1771 when Arkwright erected his mill at Cromford. This is rather confusing the issue because, by no stretch of imagination can one compare a silk throwing mill to a fully equipped cotton mill. Therefore, it will serve our purpose and help us to avoid Baines' quibble if we give Arkwright credit for being the first man fully to appreciate the vital necessity of housing under one roof those growing series of machines which ultimately became standard in the process of cotton preparation and spinning. As one writer recently said "Though Arkwright may not have actually invented the machines he claimed, yet their skilful combination into an efficient system was entirely of his creation and by far a greater achievement, for it deeply influenced the development of other industries upon the same principle." To this we can fully subscribe.

Arkwright's place as one of the greatest pioneers of industry does not rest on his claims as an inventor, nor yet upon his great excellence as a developer of crude machines, but very largely on his extraordinary organising powers and his wonderful ability to establish a system of co-operative effort. He lost the great Case but, in our estimation, although a blow to his pride this loss did not injure him nor retard his progress to any marked extent. He had reached a stage in industrial

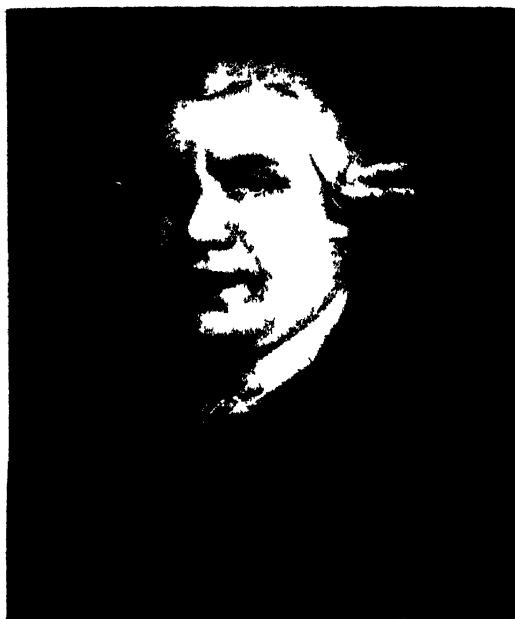
développement which did not rely for its progressive prosperity on the mere maintenance of Patent Rights. He had undoubtedly established himself as the first Master Cotton Spinner.

An effort should be made to visualise what Arkwright succeeded in doing. He set out in ordered fashion, in one building, machines, different in character and design, that were units of one comprehensive process, and for the purpose of driving them he harnessed water power. First he must have had to plan the character of his building, the space to be allotted to the various machines, and means whereby he could secure a continuous flow of material from a raw state through the various processes until it emerged a finished yarn. There was the problem of transmitting his power from his main source of supply to the various departments and machines. The question of balancing his units must have caused him considerable thought, a necessary provision whereby he avoided over or under production in any one section. As time proceeded there can be no doubt that he added more and more machines. The use of the system of drawing by rollers would no doubt be extended, and the drawing frame, the slubbing, intermediate, and roving frames, would come into being. Then no doubt he would arrange to adopt any suitable invention that would be likely to improve the rate and quality of his production. It is easy enough to improve, but the initial conception of the idea of a complete factory marked genius of a high order.

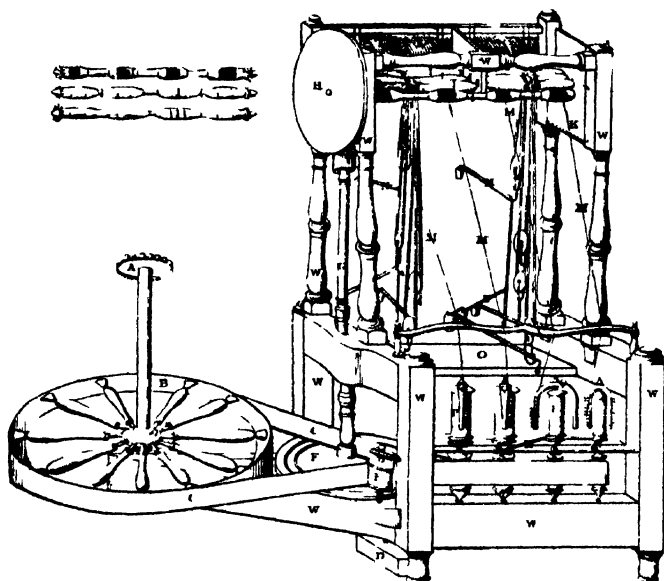
Arkwright's perseverance, his dominating personality, and his singleness of purpose were his great assets. His full belief in his powers to effect this industrial revolution and thus gain great riches and honour is evidenced by the promise to his wife when asking her to advance him money to further his objects. It will no doubt be remembered that he said he would one day be knighted and that she would ride in her carriage. Two years after they parted - through her refusal to aid him by loaning her trust fund of £400—Arkwright was paying her a yearly allowance of £500, a goodly sum in those days. That he was eventually knighted is also common knowledge, but perhaps one other fact is not so well known. After their separation Arkwright never at any time had an ill word to say about his wife although they never came together again. It is certainly a light upon his nature, which was kindly. He was keen in business but generous in his disposition.

He was blessed with certain very friendly associations, particularly that of his partner Jedediah Strutt. Opposites in religion and politics they yet remained friends all their lives, another interesting pointer to Arkwright's character. Although troubled for many years with asthmatical trouble he continued active work until his death in 1792 at the age of 60.

Can anyone doubt his greatness? He was a true pioneer, a man of unlimited energy imbued with a belief in his own ability yet appreciating to the full that success can only be attained by constant and painstaking efforts. It is fitting that we should honour him!

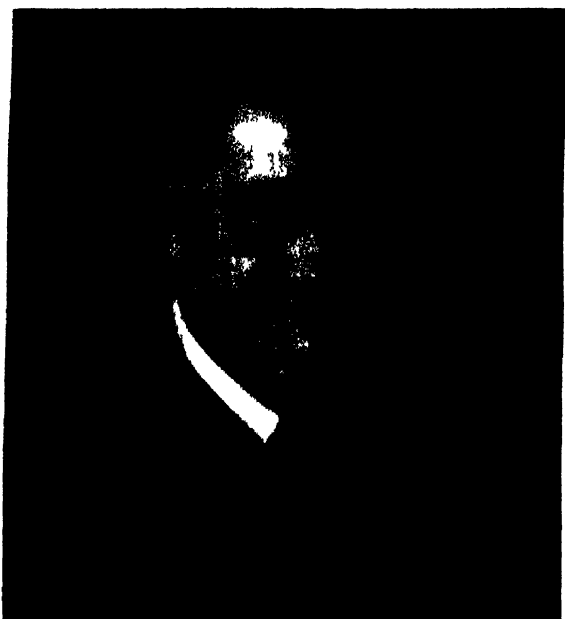


SIR RICHARD ARKWRIGHT



SIR RICHARD ARKWRIGHT'S SPINNING MACHINE Patent 1769

(From Baines's *History of the Cotton Manufacture* 1835 ')



THE EARL MR WILLIAM HOWARD J.P.
President of the Textile Institute 1926-1927-1928

NOTES AND NOTICES

The late Mr. William Howarth

At the monthly meeting of the Council of the Institute, held on the 18th January at Manchester, fitting reference was made to the death of Mr. William Howarth of Bolton, who had been an earnest supporter of the institution for many years past and who occupied the position of President for three successive years—1926-1927-1928. The Chairman of Council (Mr. Henry Binns of Bradford) paid a warm tribute to Mr. Howarth's enthusiasm for movements calculated to promote the best interests of all connected with the textile industry, and, in response to his invitation, the members of the Council stood in silence in memory of their former President. The late Mr. Howarth had experienced a remarkable career as an organisation leader in regard to the cotton industry and trade. Occupationally, he had literally gone through the mill, starting at an early age on the lowest rung of the ladder and finishing as Managing Director of the Fine Cotton Spinners' and Doublers' Association. The details of his career have already received widespread publicity and there is no need to recapitulate the particulars here. So far as this Institute is concerned, however, it is distinctly important that record should now be made of his determination to achieve something definite and permanent in connection with the Institute during the period of his presidential office. He conceived the idea of inaugurating the Scholarship Scheme, and not only did he succeed in his effort to secure funds for the purpose, but contributed personally to the Foundation Fund, the annual interest from the investments of which are available for the maintenance of the Scholarships and other schemes. It was characteristic of Mr. Howarth that in regard to this scheme he insisted that all awards should be available only to young craftsmen engaged in the industry. The conditions provide that candidature is limited to young workers unable to proceed to advanced technical training in the absence of scholarship facilities. A satisfactory maintenance allowance is also provided for the scholarship holders in order to compensate for loss of wages. The death of Mr. Howarth followed a prolonged period of illness. At the interment, which took place at Bolton on the 16th January, there was a remarkably large assembly of representatives of the cotton trade and industry and the Textile Institute was officially represented by Mr. Frank Wright, Vice-Chairman of Council, and the General Secretary.

Election of Council of the Institute

A list of the vacancies on the Council which arise before the holding of the Annual General Meeting, fixed to take place at the Institute Headquarters, Manchester, on the 17th May next, was presented at the December meeting of the Council and approved for publication. Ten of the thirty elected members retire annually, but are eligible for re-election unless disqualified by reason of non-attendance. In due course, forms will be issued to members of the Institute for nomination of candidates for the 1933 vacancies. The following is a list of names of elected members, with the order of retirement:—

1933	1934	1935
Barwick, F. W. (F.T.I.)	Barnes, H. C. (A.T.I.)	Beanland, R. J. H. (F.T.I.)
Beveridge, J. P.	Davis, Wm.	Binns, H. (F.T.I.)
Boothman, W. T. (F.T.I.)	Lishman, W. W. L.	Greg, H. Gair
Bromiley, H. (F.T.I.)	Nisbet, H. (F.T.I.)	Read, J. (F.T.I.)
Kershaw, W. (F.T.I.)	Stevenson, A. W. (F.T.I.)	Richardson, H.
Morley, Thos.	Strong, J. H. (F.T.I.)	Robinson, T. Fl. (F.T.I.)
Morton, W. E. (F.T.I.)	Vernon, W. (F.T.I.)	Slater, F. P.
*Robinson, J. (F.T.I.)	Wilkinson, W. (F.T.I.)	Speakman, J. B. (F.T.I.)
Watson, S. (F.T.I.)	Woodhouse, T. (F.T.I.)	Stott, T. S.
Withers, J. C. (F.T.I.)	Wright, F. (F.T.I.)	Thompson, G. H. (F.T.I.)

* Does not offer himself for re-election.

The Institute's Next Annual Conference

Arrangements have been entered into for the holding of the Annual Conference of the Institute for the current year at Harrogate. It is proposed to provide a programme involving organisation similar to that associated with last year's conference at Leamington. The event is to take place in the latter part of next Whit-week—Wednesday, 7th June, to Saturday, 10th June. In addition to the annual Mather Lecture, it is hoped to provide a series of papers on Problems of Finishing. Already, two or three contributions have been promised and a few special invitations have been issued. In this connection, however, the Publications Committee of the Institute, which has under consideration the matter of securing contributions, would be glad to consider proposals from Members, Associates, or Fellows of the Institute, to contribute papers on specified aspects of the general subject chosen. To facilitate the preparation of the programme of papers, offers of contributions should reach the Institute at an early date, and, in communicating, members should state the title of paper and provide a synopsis.

Institute Examination 1933

The next examination of this Institute, for applicants for the Associateship who have been approved for candidature, will take place in June next—Part I (Auxiliary Subjects) on Wednesday, 14th June, and Part II (General Textile Technology) on Wednesday, 21st June. This is the first occasion of the operation of two parts in regard to our examination. In the case of an applicant for the Associateship who has been referred to both parts of the examination, the applicant may take the complete examination in one and the same year on the appointed dates, or may take each part separately in different years. In either case, however, a candidate will not be certified as having passed Part II until he has passed Part I.

Lancashire Section Meeting

In connection with the next meeting of the Section, which is to take place at the Institute's Headquarters, Manchester, on the evening of the 8th February, there will be a departure from the announcement issued in the printed programme. In place of the lecture by Dr. N. B. Maurice, the evening will be devoted to a paper on "Recent Developments in Ring Spinning and Doubling Frames," by Mr. J. Tetlow, of Messrs. Platt Bros. & Co. Ltd., of Oldham, a contribution which will appropriately follow the lecture on "Ring and Traveller Designs and Speeds," by Mr. Donald Eadie in December last. Dr. Maurice's lecture on "Developments in Bleaching and Finishing Machinery and Processing" has been transferred to the programme of the Institute's Annual Conference (1933). As already announced, Mr. W. Wilkinson's lecture on "Problems in Weaving" will take place at the Harris Institute Technical College, Corporation Street, Preston, on the evening of the 27th January, and he will deal more especially with problems in connection with the weaving of high-grade fabrics.

The Institute's Employment Register

In connection with the Employment Register maintained at the Institute for the benefit of employers requiring candidates for appointment and of members seeking engagement, a form of particulars is now provided. Members requiring registration are asked to fill in the form so that particulars may be readily forwarded to any employer-applicant for services. In a number of instances, it has been ascertained that members whose names have been registered have subsequently received appointment but have failed to notify the Institute. For the future, therefore, it should be clearly understood that names of members will be removed from the register after a period of six months of registration unless a demand for renewal of the entry is received.

Discussion on Faults in Fabrics,

Towards the end of last year representatives of this Institute met the members of the Merchandise Committee of the Drapers' Chamber of Trade of the United Kingdom and discussed questions relative to faults in fabrics. The meeting took place at the premises of the Chamber in London. Correspondence followed, and the following conclusions were ultimately accepted—

- 1 The contacts were mutually beneficial and very helpful.
- 2 The retailers, as buyers, should insist upon having the merchandise they require, and the remedy for securing good fabrics that will not be faulty or show faults after using is really in the hands of the retailers, as buyers.
- 3 Some faults unavoidable—due to the physical characteristics of the fibres, e.g., temperature and humidity may cause shrinkage or stretching.
- 4 Variation in dyeing of Rayon involves many factors not all of which are under control.
- 5 Regarding paragraphs 3 and 4, as pointed out at the meeting these are subjects of intensive research.
- 6 Unshrinkable goods are an accomplished fact and the range available will shortly be increased. These unshrinkable finishes will increase the cost, which it is understood would present no difficulty to the distributor.

Textile Institute Diplomas

Elections to Fellowship and Associateship have been completed as follows since the appearance of the previous list (December issue of this *Journal*)—

FELLOWSHIP

SCHWARZ, Edward Robinson (Mass., U.S.A.)

ASSOCIATESHIPS

COTTERILL, Ernest (Bramtree, Essex).

GREENWOOD, Asa Shackleton (Cambuslang, Scotland).

NI TIALA, Thomas Edmund (Nelson).

Institute Membership

At the *January* meeting of the Council the following were elected to Membership of the Institute— J. T. Ashby, 3 Tuxford Walk, Gordon Road Estate, Nottingham (Mechanic, Research and Machine Design), F. Fairclough, 61 Bourne Road, Stoke, Coventry (Assistant Superintendent, Cord and Cable Dept., General Electric Co.); E. E. Feather, 293 Bradford Road, Stockbridge, Keighley (Textile Engineering Draughtsman, Prince-Smith & Stells Ltd.); J. H. Maudsley, Montreal Cottons Ltd., Valleyfield, P.Q., Canada, J. S. Mitchell, Fiona, Darvel, Ayrshire (Manager); A. E. Quinn, 176 Burnley Road, Padliham, Burnley (Student), H. B. Skaife, 9 Marlborough Street, Keighley (Sampler, Worsted Yarn Manufacture); J. K. Steel, c/o J. & P. Coats Ltd., 155 St Vincent Street, Glasgow C2 (Chief Chemist, Research Laboratories). The following were elected to Junior membership—Wm. Jopson, 45 Hanson Street, Oldham (Weaver, Firwood Manufacturing Co. Ltd.); D. A. North, "Enderleigh," Brant Avenue, Illingworth, Halifax (Apprentice Woolsorter and Woolcomber).

REVIEW

Industrial Microscopy. By Walter Garner, M.Sc., F.R.M.S. Published by Sir Isaac Pitman & Sons, London, 1932. (389 pp., Price 21/-).

The author states on the flyleaf of this book that it is "for all who use the microscope in industry" but becomes more guarded in the preface where he says that he presents an "adequate number of those methods of microscopic technique of general interest to the technical chemist." The days are long past when microscopy was a science in itself, it is now the handmaid of all science, art, and industry, and every section of this book could well demand a volume to itself. Briefly, the author has attempted an almost impossible task, although the book must be judged by its usefulness to the industrial microscopist. There is, for example, no industry in which the microscope is used to greater advantage or which has been responsible for bigger advances in microscopic technique than that of metallurgy, yet this subject is not mentioned at all in this work. In view of the demands on his space it was surely a mistake on the part of the author to introduce a chapter on microchemical technique, an exceptionally involved and highly specialised form of analysis which has actually nothing to do with microscopy at all. For the same reason it is suggested that the author might have been content to deal with microscopic technique only and not with the sciences themselves since he endeavours in a few pages to deal with botanical structures, bacteria, and fungi, whilst textile and paper-making fibres are dismissed in one of the shortest chapters of the book. The industrial microscopist requires for his work a book on manipulative microscopy dealing with his special subject, and it is unlikely that any one worker would be interested in all the miscellaneous subjects got together here. Undoubtedly the author has been at great pains to collect together a large amount of miscellaneous data on the various applications of the microscope and the book should prove interesting reading to those who require a brief summary of the use of the microscope in a number of important industrial and scientific applications.

L.G.L.

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No 2

PROCEEDINGS

London Section

Meeting at the Clothworkers' Hall, Mincing Lane, London, on Monday, 21st November 1932; Mr. G. M. Canham, of the Worshipful Company of Woolmen, in the chair.

WOOL PRODUCTION, CLASSIFICATION, AND MARKETING

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Before proceeding to deal with my lecture, I would like to express, on behalf of the Australian Wool Growers, whom I represent on this side of the world, my appreciation of the honour you have extended to me in inviting me to address you on this subject. Your Institute is, I understand, incorporated by Royal Charter, and it would seem to me that it is appropriate to address you in this old hall with all the traditions that surround the ancient Guild and Honourable Company of Clothworkers and of the Worshipful Company of Woolmen.

It is possible that, whilst you may know a great deal about the manufacturing side of the trade and of the whole-sale and retail marketing of the finished product, yet the production and marketing of the raw material, the methods pursued in various parts of the Empire and other wool-producing countries may not be so well known to you, and it is in regard to these aspects that I propose to deal.

Sheep, of sorts, are to be found in nearly every country of the world, but these are not all wool-producing, many sheep in Asiatic countries being kept for the purpose of providing their owners with milk for conversion into cheese, their skins for use as clothing, and their carcasses for food, little attention being paid to wool. Such sheep possess, in consequence, a low-grade type of wool that is only suitable for carpet purposes.

The importance to the world of the British Empire in wool production is very marked. Although the British Empire contains only *one third* of the world's sheep, yet nearly *one half* of the world's wool is produced within the Empire. The supplies of wool produced in the British Empire in 1930, computed on a greasy basis, were—

Wool Production

	Million lb.
Australia	901
Union of South Africa	290
New Zealand	266
United Kingdom	120
India	30
Canada	21
Irish Free State	15
Basutoland	10
Falkland Islands	4
Other Empire Countries	7
	1,664 = 46%
Foreign Countries	1,923
	3,587

Australia

The first settlement of *Australia* by the British was in 1788, and in the early days of the settlement much trouble was experienced owing to lack of provisions. With the object of obtaining supplies of meat and, viewing with far-seeing eye, the suitability of the country for wool production, some few merino sheep were obtained from the Cape of Good Hope in 1797. Later importations were made from Spain, Silesia, Saxony, and France. In 1807 the first shipment of merchantable wool—245 lb.—was sent to England packed in barrels. From this small beginning the industry has grown and when last year's final figures are computed the total production in Australia will be probably found to be not far short of 1,000 million pounds weight, and the sheep numbers approximately 111 millions. In all, there are about 89,000 flocks in Australia; of these about 50,000 are less than 500 in number and largely owned by farmers as supplementary to agricultural operations. The main sheep numbers, however, held solely for wool and lamb production, are held in flocks varying from 2,000 to 50,000 or over.

Australia is an island continent of sufficient area to embrace the whole of Europe. Naturally, climatic conditions vary; the northern portion is within the tropics, whilst in the south the conditions are mild and temperate, although in the winter in some of the mountainous country snow falls and winter sports can be indulged in. The main sheep districts are, however, mostly situated some distance from the coast. There the conditions are ideal for sheep raising, especially sheep of the merino or fine wool type. Climate and pastures are dry, there is abundance of sunshine, and the sheep can be left free and undisturbed in the paddocks that are allotted to them.

Sheep in Australia, as in other countries, are used as an adjunct to agriculture in the farming and closely-settled districts, but by far the greater numbers of sheep are carried in areas where the conditions of rainfall, soil, and pasturage are such as render the country only suitable for grazing.

A typical sheep station or larger holding carrying 30,000 sheep would comprise an area in the better rainfall districts of, say, 30,000 to 90,000 acres, but in the lighter rainfall areas where the rainfall would not average more than 12 to 14 inches per annum, the areas required to run a flock of 30,000 sheep would run from 150,000 acres to as large an area as 950,000 acres or even more, some properties that I have visited embracing an area of over one million acres. This land would all be fenced with post and wire fencing, the boundary being usually protected by wire rabbit netting, and in some parts with dog netting.

Inside this boundary the country is sub-divided into numerous paddocks of from 1,000 to 10,000 acres in extent, each being provided with water either from artesian, sub-artesian underground supplies, or by surface excavations, as, apart from natural supplies in rivers or lagoons which naturally only serve their immediate vicinity, most of the sheep country is not naturally watered.

Whilst the sheep are unshepherded there is ample work always on hand from shearing to shearing, not only as regards the sheep, but also in maintenance of improvements. Sheep have to be classed, culls removed from the flocks, lambs have to be tailed and marked, rams joined with the ewes, and particular care given to see that water and feed supplies are maintained.

At shearing time, the sheep are mustered and driven to a shearing shed, and placed in yards. Here the sheep are run through a race, where stragglers are removed and sheep of even ages and sexes drafted into catching pens. Shearing in Australia is now almost entirely carried out by machinery. Each shearer catches his sheep in a pen which is close handy to his stand, and after first removing the belly wool he proceeds to shear the fleece.

The fleece, which is kept intact, is picked up by one of the shed hands and carried to a large table composed of open slatts, through which any fribs, double cuts, locks, or short pieces of wool can fall. At this table the first step in the preparation of the fleece for market takes place. It is thrown upon the table and

opened completely out; any brands are first removed as these give considerable trouble to the manufacturer; the neck wool is removed, as this, although often very light in condition, is slightly different in quality or degree of fineness to the rest of the fleece. All skirtings are removed, as these often contain burr or seeds, and the breech pieces are removed. The remainder of the fleece is then rolled up and placed before the professional wool classer who, after inspecting the fleece from the point of view of condition, quality, brightness, length and soundness of staple, indicates the description or classification in which the particular fleece is to be placed.

A clip of 30,000 merino sheep would be roughly divided into the following descriptions—

<i>Super Combing</i>	...	Comprising the best, brightest conditioned, and most attractive fleeces.
<i>First Combing</i>	...	Sound, average wool, similar to super but heavier condition.
<i>Second Combing</i>	...	Shorter and heavier conditioned wool.
<i>Combing</i>	...	Tender, discoloured, and dingy fleeces.
<i>First Clothing</i>	...	Very short, fine wool.
<i>Rams</i>	...	This wool is generally of a bolder masculine type and of coarser quality.
<i>Necks</i>	...	Light conditioned wool giving a high yield.
<i>Broken</i>	...	The skirt portion of the fleece, often containing burrs.
<i>First Pieces</i>	...	The heavy portions of the skirts, mainly from the britch.
<i>Stained Pieces</i>	...	Daggy, inferior pieces.
<i>Bellies</i>	...	Often very fine.
<i>Locks</i>	...	Short fribby pieces.
Lambs would be shorn separately and their wool classed into—		
<i>Super Lambs</i>	...	The longest and brightest.
<i>First Lambs</i>	...	Shorter and heavy.
<i>Second Lambs</i>	...	Very short.

Wool from sheep of various ages and sexes are kept separate, the wool from the hoggetts, or young sheep of their first shearing, having different characteristics from that of the older sheep. In the same way, wool from ewes is often finer and softer than that of wethers, and is consequently classed separately.

The fleece, after being passed by the classer, is placed into receptacles or bins. From these the wool is removed and packed into jute packs; wool being a bulky article, these bales have to be pressed by machinery when packing; each bale weighs about 320 lb.

Sheep of the British breeds are often used for cross-breeding with the merino, especially in the colder and heavier rainfall and heavier carrying districts. In these flocks, greater care in classing is required as, apart from the $\frac{1}{2}$ -bred, $\frac{3}{4}$ -bred, and $\frac{7}{8}$ -bred, there are also perhaps types of comeback, such wool closely approaching the merino in fineness, for which provision must be made. Moreover, in all crossbred flocks there is a greater variation in the quality of the wool, some of the sheep having the characteristics of the sire in a greater or lesser degree. In pure bred merino flocks particular care is taken in the culling of the sheep and in their breeding to keep all the sheep even in type, in quality, and in character of the wool.

With smaller flocks of sheep it is not possible for the owners to make so many classes as described above, but even with comparative small clips from 5 to 10,000 sheep similar methods prevail. In most sheds of 10,000 sheep upwards, a professional classer is employed, but for smaller flocks the work of preparing the clip is often carried out by the sheep farmer himself or a member of the family who, perhaps, has undergone a course of training at the technical college. Small farmers' flocks, of which there are a large number, have to be treated somewhat

differently; these are largely sent to the wool brokers or other organisations in their mixed state, and classed and skirted and made into even lines before being offered for sale by auction.

Wool which comes from outback stations has often to be transported long distances by camel, bullock, or horse teams, or by motor lorries to the railway, and from thence taken to the coastal ports where in each state auction sales are held. The distances from the railway might extend to 200 miles, and the railway transport to the selling centre from 200 to 1,200 miles.

Most of the wool in Australia is marketed in its natural or greasy state, but in some cases the heavier, wastier descriptions are scoured in the country or after sale by auction and shipped in the scoured state in order to save freight. In certain parts of Queensland, where ample supplies of artesian bore water exist, larger quantities of wool are scoured and a very specialised product is produced. But manufacturers generally prefer to purchase the wool in the greasy state, as for their purposes they have to re-sort the wool to a higher degree of classification than that adopted on the sheep farm, and this can only be carried out on wool in the greasy state.

In the early days in Australia quite a big proportion of the wool was washed on the sheep's back with hot water and the sheep turned out in well-grassed paddocks for a few days before being shorn. Although this method produced very attractive looking wool, yet the high cost made it prohibitive, and the practice has now dropped out of use entirely in Australia.

The public auction system as practised in Australia has many advantages. All the wools are shown under exactly the same conditions and are inspected by large numbers of buyers whose competition ensures that full value will be obtained. The price of each lot is published in the press. All wools are sold under individual brands and neighbouring owners vie with one another in friendly rivalry in looking after the breeding and care of their sheep, and the preparation of their wool in order that it should command the highest price. The auction is open to the public and the owner can actually be in the saleroom and see his wool sold.

In the early days of settlement most of the wool was exported to London for sale, and was first sold by auction at Garraway's Coffee House, the bidding on each lot being limited by time regulated by one inch of candle; later, the London Wool Exchange was established, but during the last half century the system of selling the wool by auction in Australia at the principal ports has rapidly extended until now approximately 90% of the Australian clip is disposed of in this manner and shipped direct to the consuming countries. In modern practice, however, we cannot afford to regulate the sale of each lot by the candle limit described, but generally manage to dispose of an average of 400 lots per hour.

At the various centres—Sydney, Melbourne, Geelong, Brisbane, Adelaide, Perth, Hobart, and Launceston—regular sales are held, and at these auctions representative buyers from all countries are present. It is a cosmopolitan assembly as, in addition to British and Australian buyers, French, German, Belgian, Swiss, Italian, Japanese, and representatives of other countries are present, and by their competition the world's price for the wool is obtained.

In each State in Australia there exist representative organisations of growers and of brokers. These organisations send delegates to their respective Federal Councils and the two Federal Councils of growers and brokers meet periodically to agree on estimates of production and to formulate policies for carrying out an agreed programme of sales in the various centres.

On arrival at the selling brokers' store the wool is weighed in by sworn weighers, the scales being of the latest type and periodically tested. The buyers in each centre have an inspector who, at any time, can test the scales and supervise the weighing. Rules governing the conduct of the trade are drawn up by the brokers and buyers and rigidly enforced. It is in this way the trade has been built up and a spirit of mutual confidence between buyers and sellers established.

The wool stores are modern buildings and on the top floor where the wool is displayed for inspection by the buyers, particular care and attention are given to the lighting. Only a proportion of each lot is displayed, this proportion varying according to the size of the lot; for example, in a 30-bale lot only 10 bales would be shown, but in a 10-bale lot 5 bales would be made available for inspection; in small lots of five and under every bale is shown.

After the sale buyers inspect and sample the bales not shown, after which the wool is taken to the wharf sheds, "dumped" or still further pressed to economise space on the ships, and forwarded to its destination in various parts of the world.

South Africa

In the early days of settlement in *South Africa* most of the sheep were of the fat-tailed variety of native breeding, and produced only small quantities of hairy, unattractive wool.

Merino sheep were first introduced into Cape Colony by the Dutch settlers during the seventeenth century and, as noted above, some of these early importations were brought over to Australia.

During the last thirty years considerable numbers of merino sheep have been imported from Australia, thus returning the compliment. The native type of sheep has now been largely eliminated or driven into the more arid and tropical parts or native reserves. Considerable development of the sheep industry has taken place throughout the Union of South Africa during the last thirty years, and not only has considerable improvement in numbers taken place, but also considerable increase in quantity and quality of the wool.

The numbers have increased from 12 million woolled sheep and $4\frac{1}{2}$ million non-woolled sheep in 1904, to 44 million woolled sheep and 5.8 million non-woolled sheep in 1931. Most of the non-woolled sheep are in native areas. Although some fairly large flocks are maintained, the bulk of the merino sheep are pastured in smaller flocks compared with Australia. It is estimated that the majority of the flocks range in size from 600 to 2,000 head, but some few flocks amount to over 10,000 head. South African wools were at one time rather under a cloud by reason of want of care displayed in marketing, but this has been considerably improved in recent years. Skirting and classing of the wools is now undertaken in most cases on somewhat similar lines to those in vogue in Australia. Most of the sheep are shorn by hand by native labour, although machine shearing is being brought into use in some of the larger flocks.

Prior to the war most of the wool was sold to up-country dealers and by them shipped to the coast and disposed of privately or shipped to London or other overseas centres for sale. Of recent years, however, a gradual change has been brought about, and most of the wool is consigned by growers to wool brokers at the various ports where auction and private sales are conducted by wool brokers. In most ports a dual system of disposing of wool by auction and private selling is in operation.

Wool Growers' Associations exist in most of the provinces, and during the last three years a body known as the South African Wool Council has been brought into existence under Government auspices. This Council, in collaboration with the Wool Growers' organisations, is taking active steps to help the industry by improving marketing methods and, by co-operation with Australia and New Zealand, to co-ordinate marketing policies in the three Dominions. The Council also actively supports scientific research in regard to both sheep-breeding and wool-production.

New Zealand

Although in relation to Australia and South Africa, *New Zealand* is comparatively small in area, yet what it lacks in this respect is made up by the greater reliability in seasonal conditions and the high-feeding value of its pastures.

The merino sheep was first introduced into the Islands and, until the development of refrigeration, the merino type of wool predominated. With the development of the frozen meat industry, however, it was found that the production of sheep for mutton and lamb, as well as for wool, afforded the most profitable scope for development, and considerable importation of various British breeds of sheep took place for cross-breeding purposes.

The heavier rainfall conditions and rich pasturage were found infinitely more suitable for the British breeds than for the merino sheep, and on these lines of producing both wool and mutton the New Zealand pastoral industry has developed. The rich nature of the country and its suitability for closer settlement has led to the establishment of much smaller flocks than in Australia, two-thirds of the sheep in New Zealand, which in 1931 numbered 30 millions, being held in flocks of 1,000 or less.

Somewhat similar methods of shearing and preparation of the clip for the market to those existing in Australia prevail, and care is taken to keep the belly wool and britch wool separate, and the fleece is classed into even quality lines. As in Australia, many of the wool-broking houses undertake wool classing on behalf of their clients, with the result that from these small clips attractive even-quality lines are placed before the buyers.

The wool after shearing is sent to the various ports where auction sales are held. In a general way, organisation of growers and of the wool-broking houses is conducted on similar lines to those in Australia, and practically all the wool is sold on growers' account and does not pass through dealers' hands.

As in New Zealand a considerable number of natural ports exist, and as these afford a ready outlet for the wool, auction sales take place in no less than eight different centres, but the dates of sales are so arranged as to enable buyers to move from centre to centre.

United Kingdom

It is always surprising to wool men in Australia, where we are accustomed to wide spaces, to learn that in *England, Wales, Scotland, and Northern Ireland*, there are usually as many as 26 million sheep, but the fact remains and is indisputable. The amount of wool produced in the United Kingdom is approximately 120,000,000 lb. per annum.

Being less dependent on wool as a source of profit, the same care and preparation of the clip and organisation of marketing by the growers on modern lines have not been adopted in this country. Although a large quantity of the wool produced is sold in country fairs and markets, by far the greater portion of the wool shorn is sold on the farm by the growers to country dealers or wool staplers in an unclassified and unskirted state, and by them classed and skirted for sale. Most of the wools are sold privately by these wool staplers to manufacturers. Of recent years, however, developments in the way of co-operative marketing have been started and these organisations class and prepare the wool for marketing and dispose of it on behalf of their members, either by auction or private sale.

Irish Free State

Injustice would be done to *Ireland* if reference was not made to her sheep and wool production. Although small in area, the Irish Free State carries about 3½ million sheep and has hitherto exported annually between 500,000 and 600,000 sheep and lambs to the United Kingdom. Most of the flocks are small but produce very useful types of wool, similar in many respects to that of some of the British breeds.

Many of the farmers wash their sheep before shearing; no organised marketing system is adopted, local dealers purchasing the wool either direct on the farm or at local fairs, who grade the fleeces according to quality, and dispose of it either direct to the manufacturer or send it to certain large centres, such as Dublin, where wool sales are held at certain times of the year.

India

In *India* there are over 40–50,000,000 sheep, but these are not all wool producing; nevertheless the total annual wool production is estimated at about 100,000,000 lb. About half of this wool is used in the manufacture of carpets, both for domestic use and for export, and the remaining half is exported in its natural state. The greater portion of this is sent to the United Kingdom, by far the greater proportion being used in carpet manufacture. The non-woolled sheep are mostly located in the southern portion of India. The wool, which is marketed in its natural state without special preparation, is largely sold by the growers to dealers privately, or at local bazaars, but no organised system of marketing is practised.

Other Empire Countries

In *Canada*, in spite of its climatic conditions, there are between 3 and 4 million sheep. Local production is the chief interest, but in the Western States, where milder climatic conditions obtain, sheep of the merino type exist. About 20,000,000 lb. of wool is produced annually. Until 1918 wool marketing was practically unorganised, but in this year a co-operative organisation was formed which now handles the greater portion of the Canadian clip. This organisation receives the wool from the farmer, grades it into even standards, but does not skirt the wool. The organisation subsequently disposes of the wool to either Canadian or United States manufacturers, or ships the wool for sale to London.

The *Falkland Islands*' chief industry is wool production, the sheep population amounts to about 600,000, and the annual wool production, which amounts to about 4,000,000 lb., is exported to London and sold in the London saleroom.

Other Empire countries, such as *Kenya*, *South West Africa*, *Basutoland*, and *Southern Rhodesia*, are all wool producing; in Kenya the sheep industry is making somewhat promising strides.

Other Wool Producing Countries

The *Argentine Republic* now possesses a sheep population of approximately 44 millions; formerly the numbers were much greater and were largely sheep of the merino type. With the development of the refrigerated meat industry, the sheep have changed and are now mostly of the British breeds and crossbred types, and numbers have decreased by reason of the advancement of agriculture and the development of the beef industry.

The wool production amounts to about 330 million lb. per annum, the bulk of which is exported, a large proportion going to Germany, France, Belgium, Italy, and United States, and a big quantity to the United Kingdom for sale in the London market or directly to manufacturers.

In *Uruguay* the sheep number about 20 millions and, as in the *Argentine*, the development of the meat industry has led to a reduction in the numbers and character of the sheep although there is still produced a fair quantity of fine merino wool. Exports in 1931 amounted to 144,000,000 lb.

South American methods on many of the large estancias largely follow Australian practice in regard to shearing and preparation of their wool for sale, and quite a big proportion of the wools from these larger properties comes to London for sale. In regard to the smaller clips, these are mostly sold to country dealers and sent by them to consignarios situated in Buenos Ayres and Monte Video, who grade the wool in even qualities and, after displaying it in bulk in the Mercado Centrale, or Central Markets, dispose of it to overseas buyers.

Russia, although it has a big sheep population amounting to about 100,000,000, in regard to the exact numbers of which at the present time considerable doubts exist, does not produce sufficient wool to provide for its own industrial requirements. Many of the sheep are in hands of nomad tribes and wander about in search of grass and water, and produce only a small quantity of wool of inferior quality, much of which is used by the peasants for their own domestic use.

Large quantities of wool are imported annually from adjoining countries, such as Persia, Afghanistan, and Mongolia. Strenuous endeavours are being made by the Soviet Republic to improve their sheep industry, both in regard to numbers and in point of wool production, and large numbers of State Farms and Collective or Socialised Farms have, during the last few years been established, but their efforts in these directions cannot yet be regarded as successful.

In the *United States of America* considerable developments in regard to the sheep and wool industry have taken place, especially since the imposition of a high tariff on wool suitable for clothing purposes. The sheep numbers now amount to about 48,000,000, and the wool production to about 434,000,000 lb. The principle of co-operative marketing of wool has developed considerably of recent years, and there are now over 80 co-operative organisations concerned in the marketing of wool whose main object is the assembling and disposal of their members' clips, and in 1920 a method of co-ordinating their individual efforts was made which was further extended in 1928 by the formation of a National Wool Marketing Corporation.

The sale of wool by auction as practised in Australia, New Zealand, South Africa, and London, is not practised in the United States, most of the manufacturers either sending out their own agents into the country to buy from the farmer or purchasing their raw wools from merchants in Boston and Philadelphia, or other cities. The National Wool Marketing Corporation and its other co-operative organisations was formed to act practically in the capacity of a merchandising organisation, grading and sorting the wools and selling privately direct to the mills. Recently some tentative suggestions have been put forward for the establishment of auction sales of wool, but the proposals have not yet been adopted.

LONDON WOOL AUCTIONS

Although I have dealt with the wool marketing organisation overseas, this review would not be complete without mention of the London wool sales, which, being in close vicinity to manufacturing centres in England and on the Continent, have an important spot trade. Although, owing to the increased development of the overseas market, the quantity handled in London to-day is not so great as it was 30 years ago, it is still considerable, and in 1931 the total colonial wool sold amounted to 664,000 bales, this quantity including offerings from Australia, New Zealand, South Africa, and Kenya, whilst in addition considerable quantities of wool from South America and Falkland Islands, as well as a small amount of British wool, were also disposed of, the total quantity of such wools amounting in 1931 to just under 100,000 bales.

In addition, special sales of low wools from Persian Gulf, Syria, Khorassan, China, and other countries, are sold in London, the total catalogued in 1931 being some 16,000 bales. All these wools are displayed at the wool warehouses of the Port of London Authority, or other public warehouses, and after inspection by the buyers, who come from all parts of the Continent and Great Britain, are sold by auction on somewhat similar conditions to those that exist in Australia and other overseas centres; indeed, the latter have been to a very great extent modelled on the London methods.

IMPERIAL WOOL PURCHASE SCHEME AND B.A.W.R.A.

A review of wool marketing would not be complete without reference to the action taken on the initiative of the British Government in regard to wool during the war period.

At the outbreak of war all markets were demoralised and great difficulties were experienced in marketing the overseas clip of 1914-15, and prices for such wool as could be got away from producing countries began to rise considerably.

With the object of obtaining control of wool supplies, both for the Allied Forces, and to prevent supplies of wool from reaching the enemy through neutral countries, the Imperial Government in 1916 initiated a scheme for the purchase

of the whole clips of British Empire-produced wools. Under this scheme the whole of both the Australian and New Zealand wools were taken over by the British Government at a flat rate of 15½d. per lb.

The scheme in each country of origin was handled by a Central Wool Committee appointed by the Government. In Australia, the Committee, under the chairmanship of Sir John Higgins, the representative of the British and Australian Governments, consisted of representatives of growers, brokers, buyers, fellmongers or scourers, and manufacturers. In each State similar committees existed which, under the authority of the Central Committee, carried out the work of appraising, storing, and shipping the wool.

In Great Britain the scheme was administered by the Department of Munitions, the Director, Sir Arthur Goldfinch, being assisted by representatives of the various sections of the trade.

Although purchased at a flat rate per lb., the sum of money thus received in Australia had to be divided justly amongst the numerous wool growers on the basis of the quality and condition of the individual parcels of wool submitted. For the purposes of appraisal 848 different types were fixed, each having a separate clean cost value. The scheme continued until June 1920, and was then terminated. In Australia the huge total of 7,127,090 bales, or 2,274 million lb., was so dealt with during the period of the scheme. The total f.o.b. value of the wool and sheepskins amounted to £171,518,891. The conditions of sale to the British Government contained the provision that when wool was sold for civilian purposes the profits should be equally divided between the British Government and the Commonwealth Government, the latter representing the growers. The scheme, both from an administrative and financial point of view, was a complete success, but after the termination of the scheme there remained a large surplus of wool on hand and the existence of these stocks created a considerable danger to the realisation of the growing clips. After somewhat protracted negotiations it was decided that the realisation of this surplus wool should be spread over a protracted period, and a Company known as the British Australian Wool Realisation Association was formed for that purpose. This Company, the shareholders of which were the owners of wool taken over during the scheme, became the owner of half the surplus Australian wool, and was appointed agent for the sale of the British Government's half of such wools, of the New Zealand and Falkland Island wools owned by the British Government, and of certain South African wools owned by the British Government. The marketing of all these wools was carried out in a period of 3½ years in various centres in Great Britain and on the Continent, and in this period also the current wool clips of the various wool-producing countries also passed into consumption.

CONCLUSION

In this survey, much detail has been omitted, but I have endeavoured to show to you what an important part the British Empire has played in the past, and is still playing, in providing the world with its supplies of raw wool, especially for clothing purposes. Raw wool has also played and is still playing a most important part in the development of Empire Countries, and in conjunction with this production of raw wool the industry is providing the people of Great Britain with the greater portion of its supplies of mutton and lamb. The wool trade of the Dominions has provided and still provides the bulk of the freight for British shipping and enables these ships to bring other food supplies and raw materials that your manufacturers require, and in addition, provides the wherewithal to purchase British manufactured goods and payment of financial obligations in Great Britain.

During the period of prosperity the primary producer devoted most of his profits to improving and developing his property in order to make that property most productive, but his very efforts in that direction have only accentuated his unfortunate position, and we now have the peculiar paradox that in a period of

bountiful providence large numbers of unemployed exist in all countries and the economic system has narrowly escaped a complete breakdown. You will observe I use the past tense because, although there are still plenty of clouds about yet, I am convinced that the danger point has passed and that gradually there will come over the world a realisation that past policies of extreme nationalism are wrong and destructive in their incidence, and, if civilisation is to survive, a greater degree of reciprocity in trade amongst nations must be permitted to exist.

Of all raw materials, wool, in my opinion, owing to the absence of artificial schemes of stabilisation and to the absence of big accumulations of stocks, occupies a premier position, so that when the recovery really begins, it will be one of the first materials to improve its position.

It is well known that other commodities have got into unfortunate positions by reason of the artificial schemes of marketing and so-called stabilisation of prices that have been attempted and which have all failed; indeed, in my humble opinion, these schemes have largely accentuated the world's troubles. Although the wool growers' organisations in Australia have had all sorts of schemes put before them, they, as well as the producers in other Dominion countries, have steadfastly opposed the adoption of any such proposals, and have relied on the laws of supply and demand to bring about the necessary readjustment. The result has been that, in spite of very trying times, necessitating wool being sold well below its cost of production, each year's clip has been sold and put into consumption in the year in which it was produced. No accumulation of importance exists, and when times improve, as I feel sure they will, wool will reap the benefit of an enlarged market.

The lecture was followed by a good discussion and terminated in a hearty vote of thanks to Mr. Devereux.

Irish Section

Meeting at the Municipal College of Technology, Belfast, on Friday, 9th December 1932; Mr. E. Butterworth in the chair.

THE SWELLING OF CELLULOSE IN CAUSTIC ALKALIS

The first meeting of the session was held at the Municipal College of Technology, Belfast, on Friday, 9th December 1932, when a paper was contributed by Mr. S. M. Neale, M.Sc., of the College of Technology, Manchester, on "The Swelling of Cellulose in Caustic Alkalis."

There was a good attendance of members and friends. The paper, of which a summary follows, dealt with experimental facts and theories relating to the action of caustic alkalis on cellulose. The subject was viewed from a new angle and some very interesting theories were put forward with regard to the behaviour of cotton during mercerisation.

The fibrous form in which cellulose is found in nature is really an outward impression of its inner fibrous structure, of the fact that its atoms are linked very strongly in one direction (the fibre axis) and relatively weakly in other directions. Such an arrangement of thread-like molecules is characteristic of all fibres. One of its consequences is that if a fibre is placed in a solution for which it has considerable affinity it does not dissolve piecemeal like a lump of sugar or salt, but first swells greatly in diameter. On account of the intertangling of its long chain molecules great swelling is necessary before any of the molecules can escape, *i.e.* go into solution.

In the case of cellulose fibres this swelling occurs only in the diameter, the length indeed usually shows a large contraction. This could be explained by assuming that the thread-like molecular chains are inextensible and that they run in a spiral fashion along the fibre. If the arrangement is not spiral, contraction in length would still occur if, on swelling in diameter, the molecular chains are separated only between certain points of more permanent attachment—rather on

the lazy-tongs principle. It seems probable that, in the natural fibres, the molecular chains are quite continuous, or at least of very great length. When the chains are shortened by oxidation or acid attack of the cellulose, the shorter chains necessarily escape into solution more easily. This is probably the basis of the solubility number test.

All forms of cellulose exhibit maximum swelling in caustic alkalis at a moderate concentration of the latter, at higher concentrations the degree of swelling falls. This can be explained on the assumption that the swelling is due to the attraction of water from the solvent to the cellulose-alkali phase. As the concentration of alkali rises, its first effect is to increase the amount of reaction with or absorption by the cellulose. This gives rise to a concentration of alkali in the cellulose phase and a consequent osmosis or attraction of water, which results in swelling. As the concentration of alkali is further increased, the reaction with or absorption by the cellulose becomes virtually complete and further increase of alkali concentration merely increases the osmotic water attraction of the solution, so that the tendency to swell actually decreases. This purely qualitative reasoning gives some idea of how such a decrease of swelling could occur, but a complex analysis of the problem is probably necessary to account fully for the observed facts.

In the *Journal* of the Institute for 1929 the lecturer put forward a simple quantitative conception of the process* which leads to corollaries which are more or less in agreement with experience. In this treatment the cellulose gel is regarded as a single homogeneous phase, and is supposed to form an ionising sodium salt by reaction with alkali. The system is no doubt in actual fact much more complicated, but the theory is useful in affording a simple concept of the mechanism of the action of caustic alkalis. Apart from the position of the maximum swelling, which it predicts reasonably well, it explains the more intense swelling at low temperature, and the transient swelling on suddenly washing off strong alkali with cold water. The latter effect causes damage in the mercerisation of union fabrics containing viscose, and is overcome by first washing with salt solution to remove the bulk of the alkali. This transient swelling arises from the sudden osmosis or transfer of water from solution to cellulose phase which takes place when the osmotic equilibrium is violently upset by surrounding the alkali saturated fibres with water.

Mr. Neale's lecture was much appreciated, and on the proposition of Mr. Cowden, seconded by Mr. W. H. Webb (Newtownards), a hearty vote of thanks was accorded the lecturer.

Mr. J. D. Athey, the General Secretary of the Institute, was in attendance, and exhibited a number of the prize-winning fabrics and yarns in the Institute's Annual Competitions. The specimens proved of great interest and were much appreciated.

Scottish Section

Members of the Scottish Section had the privilege of visiting the works of Scottish Dyes Ltd., Grangemouth, on Friday, 13th January, 1933. There was a representative gathering from practically all districts, and the party was received by Mr. R. J. Davies, and Mr. Kerr, Works Labour Manager.

At the outset, Mr. Davies gave a short account of the history of the firm from its early stages in Carlisle at the beginning of the War, and explained the various steps which led to the formation of the present Company.

After a description of the various processes employed at the works in the manufacture of "Caledon" and "Durinol" vat dyestuffs, the members were conducted on a complete tour of the works by the firm's representatives, and had

* *J. Text. Inst.* 1929, 20, T373.

the opportunity of examining the various processes of manufacture, concluding with a visit to the Standardising Department.

Thereafter the party was entertained to tea, when the Manager, Dr. Hiscock, extended a welcome to the members of the Institute, and expressed the hope that they had had an interesting visit.

THE REORGANISATION OF THE SCOTTISH BORDER WOOLLEN TRADE

A lecture entitled as above was given in the Scottish Woollen Technical College, Galashiels, by Dr. T. Oliver, under the auspices of the Selkirk County Education Committee, and of the Scottish Section of the Textile Institute. Mr. J. Macpherson Brown, Section Chairman, presided over a good attendance. The lecture may be summarised thus—The trade may be divided under (a) materials, (b) manufacturing, (c) marketing. Attention was confined to marketing. The existing channels of cloth distribution are through—(1) merchants, (2) department stores, (3) wholesale clothing factories, (4) multiple shops, (5) mills combining merchandising and manufacturing, (6) mills selling direct to wearer.

The lecturer discoursed on existent conditions under each heading, a good knowledge of which he contended was essential to suggesting a solution to the problem of betterment. Eliminating conditions lacking promise led to his scoring off merchandising and the fifth group of manufacturer-merchant as not promising for a new start. The departmental stores were only serviceable for specialities, and the wholesale clothing factories for combined production of branded garments. The multiple shop firm often gave a better price than the wholesale clothier did. The lecturer's proposal was to start a chain of tweed shops selling Scottish Border products exclusively. The cloth may be any length or in garments "ready made" or "made to measure" in London, Leeds, or other city garment factory. Then every description of knit wear of Border origin should be offered. The project would commence with one shop and would gradually spread over the country and then to other countries, as every multiple firm has done. The lecturer adduced evidence that in 1914 he had advocated the establishing of a chain of tweed shops by a syndicate and repeatedly since that period he had returned to the subject only to be the object of ridicule; but it would have been well for Galashiels and district if more attention had been paid to his schemes 12-15 years ago. The manufacturers had spent £75,000 in a futile advertising scheme, and the excellent Trade Mark index had been frittered away for fear of a dead lion. The uncontrolled back lane sales of surplus cloth at scrap prices had militated against regular business. The lecturer reiterated what he had said in 1914, that there would still be room for firms with best connections continuing business as heretofore, but others less fortunate would require to do commission manufacturing for a selling syndicate or to strike out on speciality lines indicated in the lecture.

A stirring discussion followed on various technical points partly dealing with the grades and prices of cloth samples displayed by the lecturer, also relative to the Trade Mark and advocating of Scotch tweed and the operation of the proposed chain of shops.

On the motion of the Chairman, the lecturer was thanked for his interesting lecture and for the way he had argued the points raised with his audience.

Yorkshire Section

At the Midland Hotel, Bradford, on the evening of 2nd February, a social gathering of members of the Yorkshire Section of the Institute took place by invitation of the Chairman of Committee, Mr. J. Dumville. About 50 members were present and the Chairman was supported by Messrs. George Garnett (President of the Institute), J. Crompton (Vice-President), Professor A. F. Barker

(Vice-President), and others. Several short addresses were contributed, musical items given, and refreshments served.

Mr. Dumville welcomed the members and said that he was not only glad to express appreciation of the attendance of many individuals who had given many years of untiring service to the Institute but also of the presence of so many of the younger textile technologists. To the latter, he commended the work of preparing communications with a view to publication in the *Journal*. There was plenty of scope for effort on the part of the younger members to promote the work of the Institute.

Mr. George Garnett said that the young men of to-day entered the Institute under conditions vastly superior to those which obtained 20 years ago. The services of the Institute had been greatly developed and a stage had been reached, by long years of sacrificial effort by the pioneers in the movement, when it was a distinct privilege to be in membership and a definite honour to be possessed of the qualification of Associateship or Fellowship. He specially urged greater recognition of the importance of the application of art in relation to the production of textile fabrics.

Mr. John Crompton alluded to the falling off of students in textiles at the colleges and schools in some districts and he appealed to members to use their influence as far as possible in the maintenance of attendances. Otherwise, when the trade did revive, the industry might not be adequately prepared.

Dr. J. E. Duerden, formerly a director of wool research in South Africa and now of Leeds, said that for several years he had been concerned in South Africa with the kind of wool required by the industry. He now gladly embraced the opportunity of getting into close contact with members of the Institute. The work of the Institute was undoubtedly of extreme importance. In these days, it was necessary to be on the alert in regard to new processes and methods.

Mr. J. R. Eums spoke as an Associate of the Institute and as representing the younger members. He was not sure that employers, generally, were sufficiently alive to the opportunities provided by the Employment Register of the Institute. Young men of specialised knowledge should meet with more ready acceptance by the industry than appeared to be the case at present. The *Journal* of the Institute had been criticised as being too scientific. In his opinion, this field was largely its own and he failed to see any advantage in the introduction of matter which was already supplied by other publications.

NOTES AND NOTICES

Presidency of the Institute

The Council of the Institute has unanimously invited Sir William Clare Lees, J.P., to accept nomination for election as President at the forthcoming Annual General Meeting, which is to take place at Manchester on Wednesday, 17th May. Intimation of acceptance of the invitation was heartily welcomed by the Council at last meeting. Managing Director of the Bleachers' Association Ltd., the President-elect represents a branch of the textile industry not previously associated directly with the presidential chair. In addition to the position named, Sir William Clare Lees occupies many important offices. He is a Governor of Manchester University and a Vice-president of the Federation of British Industries. A member of the President of the Board of Trade's Advisory Council 1924-1927, and of the famous Balfour Committee 1924-1929, he was also President of Manchester Chamber of Commerce 1922-1924. The main subject of the forthcoming Annual Conference of the Institute—Problems of Finishing—will be peculiarly appropriate following the election of Sir William as President. Three Vice-presidents of the Institute are due to retire this year—Messrs. W. H. Webb, W. Turner, and F. Nasmith—and the Council has decided to nominate them for re-election.

Institute's Annual Conference

As previously announced, the next Annual Conference of our Institute will take place at Harrogate in the latter part of Whit-week of this year—from Wednesday 7th to Saturday the 10th June. The arrangements will be of similar character to those which obtained in connection with the Conference at Leamington last year. A series of papers on problems in relation to the Finishing of textiles will be contributed and the offers of contributions have already been so considerable as to leave no doubt in regard to the issue of an attractive programme. Dr. T. Oliver of Galashiels, has accepted the unanimous invitation of the Council to deliver the Mather Lecture at the Conference. The exact title of the lecture will be announced in due course, but it is expected that Dr. Oliver may draw upon his long experience of the industry and deal with (1) Materials, (2) Mechanism, and (3) Men, stressing particularly the human factor. The general papers on the subject of Finishing will deal with various problems, whilst developments in finishing machinery will also come under review.

Textile Institute Competitions

The prospectus in relation to the Institute's Annual Competitions for the current year was issued early in January. Copies may be secured on demand by any Member of the Institute interested in the programme. With minor modification, the competitions of last year are repeated, whilst an important addition has been effected by the inclusion of a section in relation to Designs for Printed Fabrics, arranged under two classes. The prizes offered in this section represent a total sum of £30. At last meeting, the Council of the Institute had to record with great satisfaction the receipt of a donation of £5, with a promise of continuance of contribution of this amount for three years, from Messrs. R. Greg & Co., of Reddish, toward the prizes in relation to the Yarns Competition. The donation comes at an opportune time in view of the reduction of income by reason of the decline in the yield of investments in connection with the scheme. The Competitions Committee would be extremely grateful for any similar contributions either on the part of firms or individuals interested in the competitions scheme. Gauged by the number of inquiries already to hand in reference to the new competition—designs for printed fabrics—there is every prospect of a satisfactory record in point of number of competitors.

Diplomas of the Institute

An interesting meeting promoted by the Yorkshire Section of the Institute, of which Mr. J. Dumville is the Chairman of the Committee, took place at Bradford Technical College, on the evening of Thursday, 16th February. Three short addresses on the subject of "The Diplomas of the Textile Institute" were contributed. The President, Mr. George Garnett, J.P., spoke on the value of the qualifications to the industry. Dr. J. B. Speakman offered some most useful observations in reference to the Examination of the Institute, whilst Mr. J. D. Athey, General Secretary, dealt with the regulations governing awards and the procedure in regard to applications. Invitations to the meeting had been extended to students and others, and there was an excellent attendance. The event fulfilled a decidedly useful purpose and the desire has been expressed that similar effort should be made in other centres.

American Scientist's Death

A member of this Institute since 1927, Dr. W. F. Edwards, of Englewood, N.J., U.S.A., has died at the age of 75 years after a distinguished career as a scientist. He was for many years in membership of a large number of learned societies and was a prolific writer of treatises on chemistry and physics. Dr. Edwards was born in Roch Island, Illinois. A graduate of the University of Michigan, he became professor of physics and chemistry at the University of Washington in Seattle. In 1897, he was elected President of the University and served until 1900, when, in the interests of industrial research, he left his educational appointment.

Federation of Textile Societies

There are now 37 textile societies and kindred organisations in membership of the above Federation, and at a recent meeting of the Committee of Management, at Manchester, it was announced that the next Annual Meeting is to take place at Oldham on Saturday, 6th May, by invitation of the Oldham Technical and Old Students' Union. Mr. F. Clegg, on behalf of the Union, attended the meeting and outlined the programme of arrangements, and Mr. H. Holroyd, of Huddersfield, as Chairman of the Committee, heartily congratulated the Oldham Association on the excellence of the arrangements contemplated. The Annual Meeting will be held at the Technical College. In the morning there will be visits to works, and in the afternoon a paper will be contributed by Mr. G. H. Thompson, F.T.I., on the industry of Oldham. Mr. E. M. Roberts, who has given distinctive service to the textile-society movement for many years past, in connection with the Bradford Textile Society, is nominated for election to the Presidency of the Federation in succession to Mr. W. Munn Rankin, M.Sc., of Burnley.

Textile Institute Diplomas

Elections to Fellowship and Associateship have been completed as follows since the appearance of the previous list (January issue of this *Journal*).—

FELLOWSHIP

FLETCHER, James Frederick (Keighley).

ASSOCIATESHIP

CROWTHER, Walter (Thornton Heath, Surrey).

Institute Membership

At the February meeting of the Council the following were elected to Membership of the Institute—*Ordinary*, E. Elliott, 92 Stormont Road, London SW11 (Textile Analyst); G. Gauld, 18 Greenfield Street, Audenshaw, Manchester (Spinning and Carding Master in India); Wm. Hardacre, Hill Crest, Bradley, near Keighley (Spinning Manager); R. P. Pitcher, c/o Airedale Combing Co. Ltd., Lower Holme, Shipley (Managing Director); Wm. Pritchard, Research Dept., Textile Laboratory, L.M.S. Railway, Derby (Textile Technologist); Lillian Stevenson, Department of Home Economics, University of Chicago, Ill., U.S.A. (Assistant Professor of Home Economics)

Junior—Thos. Bell, 12 Ossington Villas, Sherwood Street, Nottingham (Student); Geo. Clarke, Jones, Stroud & Co. Ltd., Vida Mills, Long Eaton, Notts. (in charge of Testing Dept.); O. Engelhardtson, University College, Nottingham (Student); S. Lee, 11 Ramsey Street, Bradford (Assistant Textile Designer).

The following were elected to Membership as representatives of the Textile Foundation, Washington, D.C., U.S.A.—*Ordinary*, J. B. Calkin, Baker Laboratory, Cornell University, Ithaca, N.Y., U.S.A.; Donald R. Morey, Rockefeller Hall, Ithaca, N.Y., U.S.A.; Wayne A. Sisson, Dept. of Chemistry, University of Illinois, Urbana, Ill., U.S.A.; Herbert E. Ritchey, 515 Bash Court, Champaign, Ill., U.S.A.; Wilber O. Tecters, 408 South Goodwin Avenue, Urbana, Ill., U.S.A.; Lawrence B. Haley, Alabama Polytechnic Institute, Auburn, Ala., U.S.A.; Maxwellton S. Campbell, 212 Graduate Club, Chapel Hill, N.C., U.S.A.; Donovan J. Salley, Graduate Club, Princeton University, Princeton, N.J., U.S.A.; R. L. Steinberger, Physics Laboratory, Harvard University, Cambridge, Mass., U.S.A.; John S. Reese, University of Manchester, Manchester, England.

Junior—Sidney B. Gould, 142 Southampton Row, London WC1; Orrin W. Pinea, Dept. of Physics, Massachusetts Institute of Technology, Cambridge, Mass., U.S.A.; Bryce Prindle, Massachusetts Institute of Technology, Cambridge, Mass., U.S.A.; Alfred N. Rogers, 450 Montclair Avenue, Bethlehem, Penn., U.S.A.

REVIEWS

Cellulose Acetate: its Manufacture and Applications. By A. G. Lipscomb. Published by Ernest Benn Ltd., 1933 (288 pp. and Index. Price 21/-).

In his preface the author states that it is his main intention to give a clear exposition of the manufacturing processes, and to describe the layout of plant for the manufacture of cellulose acetate and acetate rayon. A perusal of the Contents reveals that of the 290 pages contained in the book, 90 are devoted to the manufacture and properties of cellulose acetate, and this includes a lengthy consideration of the raw materials used, whereas over 100 pages are devoted to the spinning and processing of acetate rayon; other uses of cellulose acetate are dismissed in less than ten pages. The manufacture of acetate rayon must clearly be regarded as the main objective of the book.

The first chapter gives a brief historical sketch of the rayon industry, to which the history and development of cellulose acetate is incidental. Whilst it would certainly be difficult to trace the growth of the cellulose acetate industry without reference to acetate rayon it must be remembered that cellulose acetate has found wide if not abiding use in other spheres before it was successfully used in rayon production. It was not until after the war that success attended the efforts to manufacture acetate rayon, while prior to the outbreak of hostilities cellulose acetate was produced in commercial quantities in France, Switzerland, and America, in addition to the production in Germany by the Bayer Co. to which the author makes reference.

The second chapter gives a brief epitome of our present knowledge of the structure of cellulose. Here the author wisely confines his attention to recent work, dealing mainly with the chemical investigations of Haworth and his school and the physical methods of Meyer and Mark. He unfortunately omits any reference to the work of Staudinger which has lent valuable support to results obtained by the above mentioned workers. This chapter contains also a brief reference to the properties of cellulose acetate confined to questions of structure and viscosity.

In Chapter III the raw materials used in the manufacture of cellulose acetate and acetate rayon are considered. These include cellulosic materials, acetic acid, acetic anhydride, sulphuric acid, and acetone. In the manufacture of the latter the fermentation method is stressed although it is fairly certain that much of the acetone used in this country to-day is produced synthetically.

Chapter IV may be regarded as the keystone of the book since it deals with the actual manufacture of cellulose acetate. The sections dealing with pretreatment and acetylation contain a useful review of the relevant British patent specifications. Of particular interest are the sections dealing with the important operations of ripening, precipitation, washing and stabilising, and drying. Here one feels that one is in contact with the process as it is actually carried through in the works, and not as it is set out in specifications which, especially in the case of cellulose acetate, one instinctively mistrusts. One point to which reference must be made is the loose terminology used on page 60 with reference to the acetyl content of cellulose acetate. In England it is common, though not strictly correct, to refer to the acetic acid content of the theoretical triacetate as 62.5%, the Americans prefer to be more correct and express the combined acetic acid as acetyl, i.e. CH_3CO -, which for the triacetate is 44.8%. Loose usage of these terms as in the instance referred to is apt to lead to confusion.

For the thorough comprehension of the process as it is actually worked it is perhaps unfortunate that the description of the layout and plant used is delayed until a later chapter. One can always grasp the essentials of a process more easily when one can visualise it in respect of the plant and factory layout used. Great stress is laid by the author on the necessity for keeping strict and efficient record of every stage in the manufacturing process, furthermore these records should receive the careful analysis and consideration of the technical staff at frequent intervals; strangely enough this point is often overlooked.

Following in the sequence of manufacture comes the consideration of the recovery of acetic acid and the manufacture of acetic anhydride. In addition to a useful historical survey of the subject as revealed by British patents prior to 1931, the author gives a very useful balance sheet showing quantitatively the process flow including the recovery of the weak acetic acid and its conversion to glacial strength and to acetic anhydride.

The factory, production plant, and methods are considered in Chapter VI. This subject is one which has long been guarded as a trade secret and would therefore have merited fuller treatment. Numerous illustrations are given but these are, unfortunately, of well-known plant or of dismantled plant; to the uninitiated the latter gives but a poor idea of the plant as it actually functions in the factory. Line drawings and also a typical factory layout plan would have been preferable.

Chapter VII gives a comprehensive survey of the methods of control which are applied in factory and laboratory. The latter section contains a review of available methods for the analysis of materials from the raw cotton to the finished rayon. No guidance is offered as to the special suitability of any particular method in the works, and no reference is made to any accepted standards which must form the basis of laboratory control. In testing the clarity of solutions by the method described on pages 155-156, the number of c.c. of solution required to obscure the spot is surely inversely proportional to the opacity and not to the clarity as stated.

Chapter VIII contains a historical review of the British patent literature up to 1931 dealing with questions of spinning and solvent recovery; diagrams reproduced are from patent specifications. These at the best are but poor illustrations for reproduction in a text-book of this type, even more so when those selected have been several times reproduced since they were first used by Eichengrün in Herzog's "Kunstseide" published by Springer in 1927. Properties, processing, dyeing, and printing of acetate rayon are treated in Chapters IX and X, but here again it must be noted that the absence of any accepted standards robs the consideration of some of its usefulness for the works man.

Chapter XI, which summarises the other uses of cellulose acetate, gives but a poor idea of the use of this material in the manufacture of plastic and such like compositions. It is furthermore to be regretted that some of the patents cited as examples are by no means typical of the industries they are intended to represent.

The book gives a comprehensive summary of the methods available for the manufacture and processing of acetate rayon as revealed by patent literature published in the main prior to 1931, but it is unfortunate that it could not have been extended to include some of the more recent developments more especially those relating to the manufacture of cellulose acetate itself. The book is well printed and well bound. V.E.Y.

Textile Electrification. By Dr.-Ing Wilhelm Stiel. Published by George Routledge & Sons Ltd., London (600 pp. and index, price 63s. net). (Translated by A. F. Rodger)

Dr. Stiel has attempted a comprehensive treatise on the application of electricity in cotton, woollen, flax, hemp, jute, and rayon mills in one volume of some 600 pages. He has achieved this with a very great measure of success, particularly when it is taken into account that not only are the various methods of electric drive fully described, but also steam generation, steam turbines, switch gear and converting plant, and the various electric auxiliaries in textile mills.

The work is illustrated with no less than 650 diagrams, graphs, and photographs reduced to as small a size as possible without sacrificing clearness, thus leaving the maximum amount of space for the text. It is singularly and happily free from a large number of trade illustrations.

After the preface the author has followed the very good practice of dealing first with the power or primary plant, then passing on to the supply and distribution, methods of driving, and finally the lighting installation, together with descriptions of various auxiliaries such as electrical heating, air purification, magnetic separation of iron, stop motions, transport, and some electrochemical applications of electricity.

In an interesting historical survey are included many important statistical tables compiled from various official sources, one of which shows the depressing fact that the English textile industry in the matter of electrical drive lags very far behind both the U.S.A. and Germany. In Germany the degree of electrification is twice what it is in England. This is difficult to understand because the cost of electricity supplied by the large power stations to textile mills has during the last 20 years been at a reasonably low figure. Again if we compare the degrees of electrification in the engineering and textile industries in England we find the figures are 91% and 26% respectively. Can it be that, as a well-known economist once said, what is wrong with our textile industry is its personnel,

In the first section of the book dealing with the factory power-station layout is described *inter alia* that very interesting auxiliary, the Ruth steam accumulator, which has been widely adopted on the Continent, but curiously enough has hitherto been quite neglected in this country. As is well known, this apparatus is used for balancing out fluctuations in the steam consumption of the various processes and can be supplied large enough to deal with peaks of several times the value of the normal steam consumption. It is thus well adopted for use in those works requiring variable quantities of heating steam such as finishing and dyeworks.

There is a large section of the book dealing with various alternative methods of arranging group drives, illustrated with some instructive graphs comparing speed fluctuations of line shafts in various departments driven from different sources. Examples are worked out in great detail showing the variations in efficiency obtained from the different methods of grouping the drives. The advantages of individual drives are strongly emphasised and it is pointed out that the general trend of development in the textile industry is towards individual electric drive. In selecting the types of individual drive to employ, simplicity as far as possible should be the aim. Thus, the motors should be preferably of the squirrel cage type, and these where possible should be directly connected to the driven machine.

The starting gear should consist of an ordinary switch with fuses for small and medium size motors or star-delta starters where the machines start up against light load. The idea of providing starting switch gear with automatic overload and no-volt releases has the great disadvantage of making the switch gear far more expensive and complicated, and as a result many stoppages of machines are actually caused by breakdown of the control switch gear and not the motors.

Again, far neater and more efficient drives could be obtained if there were a closer collaboration between the designer of the textile machine and the electrical engineer. The lack of this is not due in any measure to the electrical manufacturers who have always been anxious to place at the disposal of the textile machinist full particulars of the design and characteristics of their motors. An example of what can be done in this respect is furnished by the comparatively young rayon industry, where the spindles are driven by direct coupled squirrel cage motors, the spindle being actually an extension of the motor shaft.

On page 180 the author makes the statement that in England ring spinning frames when individually driven by squirrel cage motors are in nearly every case provided with either automatic or hand-operated clutches, as it is thought not to be possible to obtain a sufficiently smooth start without the aid of this auxiliary mechanical device. We can, however, assure the author that his views on English practice in this respect are not quite correct, as it is common practice to drive ring frames through solid couplings by squirrel cage motors with auto-transformer starters. It has been recognised for long enough that, as the acceleration is practically constant, there is no more risk of broken ends with a directly coupled squirrel cage motor than with the ordinary drive from a line shaft.

In general, the squirrel cage motor is far more widely used in the English than in the German textile industry and this is due to the fact that the German electricity supply undertakings are far more stringent in their rules as to the use of squirrel cage motors than are their English counterparts.

Considerable space is devoted to the individual drive of ring spinning frames, with particular reference to the use of the A.C. commutator motor with automatic speed variation. He considers this the best form of individual drive for ring frames, but in spite of this we do not think it will ever become popular in England. We are aware that this form of drive has made great progress in many other countries, particularly Germany, Japan, and South America, but conditions in these countries are much different from those here. Again the expense of the equipment is several times that of the corresponding squirrel cage motor drive, since not only is the motor itself more costly but there is in addition the "automat" and the necessity for ventilating ducts. Further, the commutator motor takes up considerably more space which in most English mills, where the alley ways are as narrow as possible, is simply not available. Maintenance costs are also higher, and repairs are not so quickly nor easily carried out since the local electrical repair shop, whilst capable of undertaking repairs to squirrel cage motors, is usually out of its depth when faced with a burnt-out A.C. commutator motor.

The application of electric drive to weaving sheds is dealt with in a full and comprehensive manner and much space is devoted to various forms of individual drives, several types of various manufacturers' designs being illustrated. In passing we might mildly express our surprise that no mention of the Schorch company is made in this connection.

The author is of the opinion that for individual drives the gear drive, whether for slow or quick running looms, is always in place on account of the absence of slip when running and the higher efficiency and quotes data obtained from comparative tests in proof of this. Naturally the gear drive is much more costly than the belt drive, since the motor requires a heavy pedestal to carry it and additional outboard bearing for the loom shaft extension. Also there are the gear wheels and slipping coupling, the latter being essential to take the jar off the teeth of the driving wheels when stopping the loom. It seems rather doubtful whether this additional cost is worth while in the case of high-speed light looms.

The remaining portion of Part II deals with the drives of the various auxiliary machinery, such as calico printing machines, calenders, mangles, hydro-extractors, etc. which are treated in the same clear and precise manner.

The book is provided with a good index and a complete bibliography of works of reference arranged under different headings which much facilitates the search for further literature on the subjects treated.

Dr. Stiel is to be complimented on the high degree of completeness he has attained, without exceeding the limits of a single volume, and Messrs. George Routledge & Sons Ltd. on the excellent printing and general arrangement of the text and the large number of graphs, diagrams, and illustrations H.F.

The Heritage of Cotton. The Fibre of Two Worlds and Many Ages. By M. D. C. Crawford G. P. Putnam's Sons, New York and London (237 pages+index. Price \$3.50).

The author of this volume has spent many years in historical research in connection with the art of cotton manufacture, and has written several valuable works dealing with ancient Peruvian textiles. In this book he covers a wider field and surveys the progress of cotton manufacture throughout the ages, and in all parts of the world where it has reached any degree of importance. It is not a technical work to put into the hands of a mill manager or engineer; it presents "the story of cotton as a human drama which is not yet finished." To do this in a complete manner on 237 pages of type is impossible, but the author has written sufficient to make the story interesting and instructive. "Cotton has brought wealth and power, poverty and degradation, in its history." Truly a human drama which everyone interested in cotton should read.

The author believes that the origin of spinning takes us back to the most primitive peoples who wore no garments (except the skins of animals), neither used baskets nor pottery, and yet knew how to make cords of fibrous materials as an essential part of the bow and arrows of their hunting equipment. Weaving on the other hand was probably developed first in the making of fish traps of sticks interlaced with pliable saplings and vines, later baskets and rugs were made of rushes and coarse grasses, and finally softer elements were produced and used as clothing and ornaments for the human body. The art of pattern production by colouring the woven strands and by painting appears as ancient as the art of weaving, and was an essential part of the garment from earliest times.

There is no doubt that in two parts of the world the art of cotton manufacture had been developed to a remarkable degree many centuries before the Christian Era, and the author has put on record many of the discoveries that have been brought to light in the sandy plains of ancient Peru. The discoveries are remarkable and reveal a very high standard of culture and efficiency amongst a people who have been entirely lost in the history of the human race. Yarns as fine as 200 count, also folded and crepe yarns were used, and tapestries, brocades, warp and weft stripes, leno, double cloths, crocheting and laces, dating back to 650 B.C., have all been analysed. For many centuries the natives of Peru and Mexico have made fabrics from the native grown cottons. Columbus found that cotton garments were worn by the people of the Bahama Islands when he landed there in 1493.

The original home of the world's cotton industries, however, was in the East, and a similar story is told of the excellence of Indian cotton goods as early as 800 B.C. Remarkable skill in producing fine yarns and fabrics, and in the art of

dyeing and printing are revealed. International trade in cotton goods was not of great importance until the Mohammedan conquests of the seventh and eighth centuries, and it is to the same influence that the art of cotton manufacturing was established in Spain a thousand years ago. The important manufacturing centres moved from country to country throughout Europe in the Middle Ages. Italian weavers and merchants were famous in the twelfth century, those of South Germany in the fourteenth, France and Flanders in the fifteenth, finally those of England in the sixteenth and seventeenth centuries, and growing so formidable as to be disconcerting to the English wool merchants of the seventeenth and early eighteenth centuries.

The story is continued of the developments that took place in England, changing for all time the methods of manufacture and industrialising what had hitherto been a semi-domestic occupation. So the greatest of all the industries was established thousands of miles away from the sources of supply of raw materials, and dominated the cotton industries of the world for over a century. Very early we find that the new English manufacture was the envy of the world and our author carries us over to America again in company with the skilled artisans of Richard Arkwright and others to found the great textile industries of that country as far back as 1790. Later chapters have to do with the development and organisation of the cotton industry, first in the Eastern States, and later in the Southern States of U.S.A., and the author gives much information which will probably be new to most readers.

Mr. Crawford is no lover of the mechanical age and expresses his convictions in no uncertain tones; for example, "This world has not been cured of its love of beauty because some few men own cotton mills." Again, "The fact that automatic machinery is one of the great conquests of modern civilisation, does not change the fact that people desire merchandise for its æsthetic rather than its economic value, and the attitude of the world towards beauty has not changed merely at the behest of mentally stagnant mill treasurers who have followed out the ideas developed by a small group of brilliant mechanics in England in the latter part of the eighteenth century."

Truly a very readable book.

There are 21 plates of illustrations, showing museum specimens of ancient fabrics and implements, and a chronological table, bibliography, and index are included. There are several misprints such as Picks for Picts, p. 21; stick for thick, p. 23; combs for cones, p. 54; Lord Leverholm for Lord Leverhulme, p. 114. J.R.

GENERAL ITEM

National Institution of the Boot and Shoe Industry

(Extracts* from an address by Mr. J. H. Lester)

At Norwich on 27th February 1932, before a meeting of the Institution an address, extracted below, was delivered on "The Aims and Functions of Institutions with Special Reference to the Textile Institute" by Mr. J. H. Lester. Mr. G. W. Hunt, Vice-President of the Institution presided.

"It may well be the ambition of your Institution to take and to deserve a proper place among the many technical societies whose object is to establish on firm foundation, to foster, and to advance the great industries of this country.

Your aims are national, as they certainly should be, but let us not forget that knowledge, science, and technology are world wide, both in the giving and in the receiving, and while our aims are national, we must not be insular in our outlook, nor must we hope to receive without giving in return.

The Chemical, Physical, Botanical, and similar Societies are mainly interested in the advancement of the Pure Sciences, *i.e.* in accumulations of scientific knowledge, whether that knowledge can be at once utilised in industry or not.

Naturally your Society is more closely comparable with the Society of Chemical Industry, the Society of Dyers and Colourists, the Institution of the Rubber

*The full text of this address appeared in the *Journal of the National Institution of the Boot and Shoe Industry* for October, 1932, and is extracted here by permission of the Council of the Institution, and of the speaker.—EDITOR.

Industry, and the Textile Institute, than it is with the purely scientific societies. There is a natural and proper tendency for you to be more interested in, and concerned with, industrial success, craftsmanship, mechanical processes, and the results of long and intensely practical experience.

This generalisation is important because you will, I think, be disappointed if you expect to create within your ranks the same proportion of scientists that we necessarily find in the societies that are so closely allied with Pure Science. The Boot and Shoe Industry at its best requires all the scientific knowledge and experience it can obtain or create, but it can hardly be said as yet that you depend for your very existence upon a high proportion of knowledge of, and experience in, Chemistry and Physics.

These remarks, then, in no way depreciate the value of science, but whatever our hopes for the future may be, it will be wise for us to look at the industry as we find it to-day, and particularly for us to recognise that, apart from very recent progress, science has contributed in only very small measure to the building up of our business.

Science has already helped very largely towards adding to the beauty and the utility of our products, and we know very well that if we want to maintain our quality, to keep abreast of the world's production, and particularly if we wish to take the lead over other nations, we shall be compelled to use science in far greater degree than we have done hitherto.

I am anxious, however, that we should not overlook the vast experience and knowledge of detail that has already been accumulated, for there is some fear of mass and machine production creating classes of specialised experts, and that we may lose that *wider*, though perhaps shallower experience, possessed by the hand worker. That danger exists throughout every industry to-day, and it is not more strongly marked than in the cotton industry, where it has been said with some truth that you could count on the fingers of one hand the number of technical men *who* have a reasonably complete knowledge of *all* the processes of that industry.

Science and research *can* do much for our industry, but we must not expect too much from them. It cannot be denied that the results of intensive industrial research during very recent years have been disappointing to many business men who have subscribed to the Research Associations—who, . . . begin now to learn that there is no magic in science or in research, but that it is just a form of hard work, of close study, and of logical thinking.

To rely mainly upon the efforts of *any* industrial research organisation would in my opinion be almost criminal, for no real application of science to the industry can be made until it permeates the staff of the several factories. It is hardly conceivable that the contact between science and industry can be very far reaching in its effects until those who are concerned with the materials and processes at first hand are working side by side with the scientists. Better still if these technologists, as we may call them, start their career with some real training in science.

While the objects of your Institution clearly contemplate the encouragement and advancement of technical education, I can find no specific claim that the application of science to industry is among them. It may be inferred of course, that science is a necessary means of promoting education, technology, and research, and that, I think, must have been and should be the case.

My real and main object to-day is to give you an intensely practical idea of what science is and what it can do for your industry. Let us try to get some first-hand knowledge of what it is. In its broadest sense science is just knowledge. I am concerned with that kind of science or knowledge which has to deal with the material things that we see around us and that we have to deal with in our works—leather, cements, dyes, nails, machines, and all other things and processes that are used in our factories and warehouses.

It is quite obvious that greatly extended knowledge is needed, and here it is that science—as it is known in universities and schools—becomes useful and becomes essential to progress. This material science has to do with all that mass of knowledge, which concerns weighing and measuring, not merely weighing in scales and measuring in inches, but also in 'weighing' or 'measuring' all kinds of properties that these material things possess. Just think how many such physical properties and characters a single substance like leather possesses. Apply the

same ideas of measurement to all the other things found in the factory, and we get some idea of the ground covered by the Science of Physics and of its relation to the making of boots and shoes. Further, we have all the measurements that the science of chemistry teaches us to apply to all those materials. Chemistry will teach us not only the kind of change, but it can measure the amount of change that takes place in our materials whenever chemical change occurs. Often enough it happens that a knowledge of science helps us to avoid running after some imaginary advantage that a new product might have, and indeed our patent records are strewn with countless wrecks of utterly useless inventions that would never have reached the Patent Office but for the ignorance of scientific facts.

Whatever we may think of Confucius for being an agnostic in spiritual matters, we can admire him because it was said of him 'The master had no interest in magic.' That is surely the attitude of every scientific man, for it means, if anything, that knowledge must be proved to be true in the light of knowledge already in our possession.

In the Middle Ages, and for many centuries the Sciences of Physics and Chemistry made very slow progress, largely due to confounding things that were not understood with either occult or spiritual things, until the Reformation introduced greater freedom of thought and made search or research into the unknown possible, and of course attractive, to every seeker of the truth instead of being repulsive and dangerous.

Coming to still later times, it is beyond question that by far the greatest stimulant science has received was contemporary with what we call the Industrial Revolution in this country, when we surpassed every other nation in the world, owing to the efforts of Watt, Stephenson, Arkwright, Cartwright, Brindley, Faraday, Sir Humphry Davy, and a hundred others of the same age, whose names will never be forgotten.

Whether we think of iron, of cotton, of leather, or of dyes, we see that the pace still grows hotter in the thirst for new knowledge. My own experience of scientific literature in bygone years was that I could, without much labour, keep pretty well abreast of all the technical journals that interested me, but to-day their name is legion, their bulk is stupendous, and there is nothing for it but to spend more time in keeping abreast of current knowledge, but to restrict one's interests.

Let me give one word of counsel to every student who may hear me, and I hope none of us are too old to be proud of being students. Read all you possibly can of the technical and scientific journals that deal with the daily advancing knowledge of your industry. Make a start right away with this month's technical and scientific journals; learn to distinguish between the writings that are worth reading and the acres of weariness that ignorant editors produce; and, if after reading these journals for a few months you fail to find them useful and interesting, take my final piece of advice, abandon the hope of being much use to your industry or if its being much use to you.

One of the lessons that many industries are learning to-day is that the physicist must take a far more prominent place as a scientist in industry than hitherto. In the textile, boot and shoe, iron and steel, and many other industries, I am confident that the next few years will show a rapidly increasing demand for physicists. The recognition of the value of the physicist is of very recent date. Since most of your operations in the making of boots and shoes are of a mechanical nature, and but few are chemical, you may find this branch of science of at least as much value as chemistry. When we remember that physics takes under its wing the whole of the 'sub-sciences' of mechanics, electricity, sound, light, and heat, it seems clear enough that men who have been thoroughly trained in the fundamentals of these subjects are sure to be needed and used in your industry.

Whether the current academic training of physicists is what industry requires is, I think, open to doubt; and my experience is that the properties of materials of construction and a working knowledge of steam, air, ventilation, and humidity—and such-like things—should receive a far more important place in the curriculum, even if atomic structure, the colloidal state and the more advanced mathematics have to be curtailed.

The educated man is commonly regarded as one who has at any rate a fairly considerable acquaintance with English, history, geography, perhaps a foreign

language or two, the classics, and perhaps mathematics, but I fail to see that a man who has hardly any of these qualifications should not be considered 'educated,' if he knows the compositions and properties of the objects which surround him, of their uses and of how they are made—in short if he is a 'material scientist.' Education in general should *begin* with the study of material things and their uses and properties. The 'value of evidence' would be learned from observations, permitting of proof by measurement of any kind. Even as a sound foundation for *other* studies and as a means of training the mind in matters that can *not* be weighed and measured, such a course would be invaluable as a *means of learning and proving the truth, and to compel logical thinking*. That I believe, is the avowed object of education rather than to cram the brain with facts and theories.

While the elevating influence of literature, art, civics, and politics is universally admitted, . . . we may well ask whether it is fair to avoid educating our youth in a knowledge of those material things with which they are surrounded in their daily tasks, the leather, coal, iron, plaster, wood, water, and machines which they handle every day, and out of which they earn a weekly wage. A merely rational education would surely teach something of those material things which, for 90% of the population, must be the means of, or the tools, for earning daily bread.

Now let us deal with some of the experiences in the early years of the Textile Institute, in so far as they may be of interest to you.

From our earliest meetings, prior to incorporation, we recognised that the percentage of those engaged in the industry, whom we could bring into the Institute would be but small. We would have been quite happy to find as many as 5% of the textile firms or companies so far interested as to join us. This was largely due to the fact that so many makers of textile material conduct only a single process, who think they have nothing to learn about that single process and do not want to learn what happens to the material before it comes to them or after they have disposed of it. But what is common to all industry is that the value of *thorough* knowledge of materials and processes is too seldom regarded as being essential to profits and progress. It becomes then one of the functions of such institutes as yours and ours to educate the fully grown manufacturer into an appreciation of the benefits of science in its very widest sense, as well as to educate our rising youth in the schools into those habits of thought that will make for an ever-increasing thirst for knowledge. May you succeed in attracting far more than 5% of your manufacturers into your fold.

Our object in granting Associateships and Fellowships of the Textile Institute has been to educate men to become textile technologists, and we have defined the technologist as one who combines knowledge of, and experience in the materials and processes of our industry with knowledge of and experience in the underlying sciences, particularly physics and chemistry.

I have now dealt, to some extent, with the value of science to industry as one of the main objects of our, and similar institutions, and education has of course taken its place as one of the avenues to that objective, as also has the conferring of diplomas. It remains then to deal with publication and with the conduct of a journal. Everyone of course thinks he could run a newspaper or a journal, but many have regretted the day they tried. You have acted most wisely in not being too ambitious, by not starting right away with a monthly issue. We are certainly proud of our monthly Textile Institute *Journal*, if only by reason of its circulation and the reputation it has gained at home and abroad. It still needs—and I think badly needs—improvement, but such measure of success as it has achieved is, I feel sure, due to the maintenance of a high standard, to the ruthless rejection of "pot boilers," to encouraging the publication of research by all possible means, and to the inclusion of abstracts of current literature. And let me here say to any student who aspires to keeping well abreast of current knowledge of his subject, and wants to rise above his fellows—that the compilation of abstracts from foreign journals offers an opportunity he should take advantage of. Some of the journals offer remuneration which, while not very great, is quite worth having. Particularly would I urge *Associates* to get to work on abstracting as soon as possible, following this up by contributions that are worthy of publication. Much of the matter submitted for publication is by no means confined to describing the result of one's own research work, and mere practice and facility in putting thoughts on paper is, of course, up to a certain point, essential to the writing of a thesis.

Just a few words about the use and value of degrees and of initials following our names. May I lay it down that, while the general public has but a faint idea of the value of degrees in general or in particular, the real and deserved value of all titles, degrees, or initials, depends entirely upon the work involved in obtaining each and every such distinction. When academic and technical qualifications are in question, it may be said that their value is proportionate merely to the length and quality of the courses of study involved and to the severity of the examination. In the higher class of degrees, and as in your Fellowship, it is usual to require the production of a thesis which shall have a basis of original work.

I have made some inquiry as to the authority behind the recognised degrees, but not with much success. There appears to be no question as to the authority of the usual degrees given by the Universities, and that Chartered Institutions, such as the Accountants, Institute of Chemistry, and the Textile Institute are vested in such authority that they can prevent unauthorised persons from using those degrees, titles, or initials. There is nothing to prevent anyone from using any initials he likes, provided that he does not trespass by using letters whose use is prevented by Royal Charter or otherwise.

It is well to regard all degrees, however authorised, as not conferring any honour or status whatever beyond this, that the individual holds what we may call a certificate, saying he has passed certain examinations and has had a certain amount of experience.

There is some fear, and it applies to all the Institutes we are discussing, of the Associateship being regarded as an end in itself, but I would strongly urge that it be regarded as indicating that the possessor is a person 'suitable to associate with' those who have entered the next higher grade—generally the Fellows. The Associateship should be always regarded as a stepping stone to the Fellowship. It is well to carry this idea still further and to recognise that every academic examination, from the lowest to the highest, is but a stepping stone to something higher still. Even in the case of the man who has a long string of letters after his name, his real worth and value are by no means described thereby; indeed, the longer the string of middleclass degrees he has, the greater becomes the suspicion that he is what we know as a degree hunter, and that he may be parading his virtues to hide the things he lacks.

In every industry that I know fairly well, there is a demand for standardisation in the sense that there obviously should be universal standards of *size* for such things as screws, nuts and bolts, and motor car tyres. Probably your industry requires such standards and your institution would probably be the body to advocate or possibly to compel the adoption of such standards throughout the trade.

The standardisation of methods of mechanical *testing* and of chemical analysis will probably come within your trade requirements, and if so I would urge the wisdom of regarding all such standards, as you may fix, as being only of a temporary nature, and to be altered and improved with advancing knowledge. In far too many instances, standardisation which has become obsolete, has been a bar rather than a help to progress.

One of your difficulties, and particularly that of your general and branch secretaries, will be to get competent persons to give lectures, read papers, and increase the knowledge of technical matters among your members. I mention this because I want you to regard membership of your Institution far more as a means of spreading knowledge than as something which will give a return for the amount of your subscription. You owe your livelihood to your industry, and I would wish that you would repay that debt in some measure by the most direct means possible—that is in helping the Institution. And there is, I believe, no more direct means of helping any society than in helping the secretary in a very difficult task, and particularly by *increasing* the bulk and improving the quality of knowledge that is broadcast to your Institution."

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PROCEEDINGS

BRITISH INDUSTRIES FAIR 1933

TEXTILES SECTION, White City, Shepherd's Bush, London

This survey has been prepared at the request of the Publications Committee by Mr. W. Wilkinson, of Blackburn, who deals with the technical aspect of fabrics exhibited; by a prominent Manchester producer, who reports on designs and colour; and by Mr. A. Trevor Hundley, of Southsea, whose point of view is that of the distributor.

A Technical Survey of the Exhibits. By W. Wilkinson (Fellow).

A preliminary, yet fairly thorough, general scrutiny of the exhibition created one or two broad impressions which may be worth recording before turning to details of fabrics which were subsequently examined more attentively.

The exhibition must first be regarded as a gigantic shop window for the textile products of Great Britain and Northern Ireland. The broad effect, due mainly to the decoration of the halls themselves and to the general character of the stands, coupled with the excellent colour effects very definitely achieved by many exhibitors, was extremely good. Closer inspection revealed lack of balance and variations in intensity which must have had the effect of reducing the attractiveness of sections of the exhibition. What is meant is that certain sections or individual stands either did not display their goods to the best advantage, usually because they had too many good things to show in a restricted space, or, in a few cases it must be admitted, because their displays were not up to the general level of quality. Of the colour effects and how these were secured, another contributor will write in detail, but the opinion must be noted here that the general display owed at least 70% of its effectiveness to colour alone.

A minor point perhaps may be admitted to reference, since it certainly was real enough in the impression it made. It is that where a general plan has been adopted in regard to stands, any marked deviation from that plan repels rather than attracts attention.

Of fabric structures exhibited, it may, first, be stated that nothing absolutely new was noted. Since "there is nothing new under the sun" this is not perhaps to be wondered at, but claims made by salesmen that "This is absolutely new, sir," cannot be substantiated and certainly are not impressive.

On the other hand, the successful development or extension of an old idea to the point of commercial availability is a noteworthy achievement and several fabrics on show come into this category and to that extent may be called "new": their producers are to be heartily congratulated on their solutions of the technical problems presented.

Taking all fabrics exhibited by groups—the grouping adopted by this Institute in connection with its Fabric Competitions was adopted in this survey—that containing "Fabrics for Furnishing purposes" was outstanding at the exhibition.

All sections, cotton, wool, silk, linen and rayon, contributed their quota to this successful group, and some admirable fabrics, particularly soft furnishings, were on show. One "new" structure merits specific reference; this is a double velveteen, a reversible fabric, covered by a provisional Patent 3903/1932. It is a weft pile fabric, hence is a velveteen and not a true velvet, of about 375 picks to the inch, with the fast pile on both faces. Its density is such that when placed over a 100-watt lamp no light penetration occurs, and its colourings and finish are admirable. The quality of cotton used is such that excellent lustre is secured and the dyeing of the samples exhibited is a testimony to the dyer responsible. Its appeal as a reversible furnishing fabric with good wearing and draping qualities, coupled with its excellent appearance, should be very wide.

As an example of the need to make an appeal through the medium of the fibre employed, reference may be made to mohair pile fabrics exhibited in the soft furnishings group. Here distinctive "handle" is secured, whilst large jacquard patterns are introduced successfully. Imitation skins were noted as examples of enterprise in the substitution of textile products for more expensive goods. The employment of mohair yields clean, hard wearing, non-depressible pile fabrics.

More than one example was noted among furnishing fabrics of the employment of elaborate jacquard designs and effects. The introduction of jacquards of fine pitch and high needle capacity has resulted in the production of some excellent furnishings and Lancashire manufacturers might note that their Yorkshire and Scottish confrères seem mainly to be exploiting this development.

Coupled with the above-mentioned development, one exhibitor had introduced slub and condenser weft yarns with rayon warps into a series of outstanding fabrics for furnishing purposes. Cheaper lines utilising cotton warps and grandrelle wefts, as well as more expensive goods carrying woollen wefts were also shown, and the "historic" character of the goods added to their attractiveness—nothing better in range, structure and conception was to be seen. The wealth of goods available on the small stand utilised was its only drawback. No group excelled the furnishing fabrics in the Fair in regard to technical excellence and enterprise.

Book cloths are not, of course, new, but those on the stand of one exhibitor being "fadeless," non-spotting, and washable, struck a new note and are worthy of remark. Their attractive colouring, too, added to their appeal and they should be much in demand.

The principal "weave" employed in the women's dress goods group was the so-called pique voile, which should more properly be termed the "cord" voile. As a background for printed designs it is most effective, though evidence was seen of its break-down into "cheaper" lines by the employment of single yarns instead of two-fold, and by the securing of the same effect by printing alone.

Dress goods made on lace machines attracted attention and examples in checks and diagonal lines of cotton and wool substance were seen. These were of firmer structure than is usually secured on the lace machine and the tendency to "droop" was apparently overcome.

"Shadowlaine" is a name given to another "new" structure noted. This fabric is a cord with a silk handle. The structure is of the cord type with a spacing of plain fabric between the cords. Hard twisted worsted weft is employed, which brings the cords together, resulting in a springy fabric with a softer "feel" and better draping qualities. The same exhibitor showed very suitable yarn structures in union suitings designed not only for tropical wear, but to create so far as may be a demand on the part of "mere man" for light-weight attractive summer suitings. According to this theory the women are not to be the sole wearers of "clothing for the season."

No one would claim that the "cellular" structure was new; it would not be easy to say how long the "leno" weave has existed, but the extension of the

principle to yarns of different fibres and of heavier counts indicates enterprise and may be marked as progress. Examples of this fabric structure applied to sheets, bed spreads, light and heavy blankets, and suitings were to be seen. In one instance, at least, a chenille yarn had been introduced with excellent effect. Coupled with very attractive pastel shades in colourings, these fabrics were a good second to the soft furnishings.

For overseas markets further afield than the Continent of Europe, it was not to be expected that much could or would be exhibited, but one stand bore examples of West African goods in very vivid checks with rib structure patches of coloured rayon. These were novel and very attractive.

Space is not given here to the several examples of "uncrushable" fabrics, whether they derived that quality from their weave or from finishing processes. They have been described elsewhere in the literature at length on previous occasions.

Viewed geographically, though it may be said that Yorkshire and Scotland came more prominently into the picture this year: it may be that more experience in the display of their goods will enable these manufacturers to catch up with their Lancashire rivals in this aspect of industry. On the other hand, though quality masked may miss its object, lack-of-quality displayed does not always achieve its ends. It would seem that the Midlands and Ireland ought to claim a bigger share of the space available on such an occasion.

A new development in fabrics for underwear has been made possible by the introduction of weft yarns produced without twist, giving a soft silky feel and draping qualities almost equal to real silk. This yarn is being spun on special frames and is treated with a solution of an adhesive which when dry gives the necessary strength to the yarn and the resulting texture is in no way reduced in strength. Limbrics and other soft-faced fabrics are now being produced with this twistless weft and finished in pastel colours. The effect is very pleasing and one wonders how far the variation of twist (ranging from yarn without twist to yarns with a considerable number of turns per inch) will be responsible for a good portion of the future trade of Lancashire and Yorkshire.

Hard twisted weft is sized or doped to keep the twist and, at the other end of the twist scale, yarn without twist is sized to give strength sufficient for the weaving process.

Sizing weft yarn may be one of the problems for the future, and weaving sized weft will certainly be one of the developments in the textile industries.

Design and Colour Survey. By a Manufacturer.

On visiting the Textile Exhibition at the White City, the visitor felt overwhelmed by the enormous display of printed fabrics. The exhibition was laid out in long avenues with the stands on both sides displaying a multitude of printed fabrics produced by Lancashire and Yorkshire firms.

Apparently exhibitors imagined that the interest of buyers would be confined to prints, as with one or two exceptions every stand portrayed printed designs. For display purposes bright designs are no doubt attractive to the sight, but the exhibition failed to represent the great variety of beautiful plain dyed fabrics which Lancashire has put on the market during the last few years—fabrics which have replaced the Continental real silk and artificial silk fabrics formerly imported.

In the printed fabrics it was noticeable that each annual exhibition shows a great advance both in design and colour. The most popular and attractive designs this year were undoubtedly diagonal effects, chevrons and broken checks, all in very bright colours—blue, red, brown and gold predominating. There

were also some very attractive fancy spot designs on light grounds, suitable for summer wear.

The floral designs, although beautiful in design and colour, were not as striking as the above-mentioned styles, and did not show much advance on last year's exhibition. The fabrics printed in floral effects consisted of medium sized objects, not closely set, and the whole exhibition of these showed a definite leaning towards natural flowers rather than conventional. The colourings were mostly tones of blue, red, brown, and gold, and a soft shade of grey which is likely to be popular this year. Green did not appear to be in fashion, as there was an absence of this colour. One stand in particular had a very beautiful display of voiles and chiffons, all in light pastel shades—pinks, beige, and lemon predominating.

Two or three stands showed a good range of designs for children's wear in small (mostly geometrical) effects in bright colours on light grounds, which gave a very pleasing clean appearance to the cloth. These were all in fadeless colourings guaranteed to stand washing. This important section of the trade did not appear to receive the full attention which it deserved, and the great majority of the firms omitted to show any designs for children's wear.

The qualities of cloths which were printed consisted mostly of uncrushable crêpes, voiles, and chiffons. The large range of uncrushable qualities demonstrated the big advancement which Lancashire has made in the improvement of cotton and artificial silk fabrics.

There were some quite new fabrics introduced in heavy rough crêpe styles which are bound to be popular. These qualities are as good as anything seen from the Continent and should sell in large quantities in the plain dyed state, as well as printed.

The Retailer's Point of View. By. A. Trevor Handley (Southsea)

This year's exhibition marks a very great advance on the previous exhibitions in the Furnishing Fabric Section.

The various manufactures and factors are conveniently grouped together and the standard of the stall dressing has reached a very high level. It is a great convenience for retail buyers to be able to pass from stand to stand making comparisons of the various designs and colourings in comfort and ease.

Taking the section as a whole, the retailer must be struck at once by the fact that as far as designs are concerned, the modernist spirit seems to be declining, and there is a reversion to the more traditional period designs. The familiar and many very ugly jazz designs and colours appear to be almost non-existent. The colours themselves, both in plain and printed fabrics, show a much softer tendency, and the delightful shades of soft green, russet and new pink, which savours a little of terra-cotta, seem to predominate.

Another predominant note is the growth of glazed chintzes, which in many cases are quilted in various designs and appliques, which unquestionably enhance their appearance.

This year's exhibition also shows a very striking advance which has been made in the manufacture of artificial silk fabrics. Not very long ago they were somewhat crude in their colourings and particularly harsh in their texture, whereas now one is able to find most delightful shades in fast colour dyes and soft textures, reminiscent of pure silk.

London Section

Meeting at the Institute's Rooms, 104 Newgate Street, London, on 16th November 1932; Mr. Frank Henley in the chair.

LEGISLATION CONSIDERED IN RELATION TO RETAIL DISTRIBUTION; ITS ORIGIN AND DEFECTS

By G. B. BROOKS

The word "legislation," according to Wharton's Law Lexicon, is "the act of giving or enacting laws," but in everyday parlance the word is generally understood as indicating the collective body of laws which have from time to time been enacted by the Legislature. Laws in this sense are understood to mean Statutory Enactments of the Supreme Legislative Power, *i.e.* Acts of Parliament, as distinguished from law which has grown up from time immemorial, derived from legal principles and judicial precedents, and known as the Common Law. There has always been a sharp distinction drawn between these two classes of law. The Romans, following the earlier example of the Greeks, called the one branch *Lex Scripta*—the written law—and the other *Lex non Scripta*—the unwritten.

It does not, in the least, follow that because the law purports to be set out and defined in an Act of Parliament, it is thereby made clear and unambiguous, therefore, a third class of law arises which consists of written or Statute law as explained by the judges with the aid of these customs, rules, and maxims which are the Common Law.

In dealing with this subject, however, I have to confine myself as far as I can to the effects which the former class, namely, direct Acts of the Legislature, have had upon the retail and distributive trades. It is, in itself, a very wide field and I will only call attention to one or two of the principal Statutes which affect retail traders in the conduct of their business as distinguished from those which affect them, in common with everyone else, as ordinary citizens.

These seem to fall automatically under two heads or classes—

CLASS I—Statutes which affect the trader's relations with the public or the State.

CLASS II—Statutes which affect his relations with persons in his employ.

Class I readily adapts itself to sub-division into three headings—

A—His relations with those from whom he purchases his goods.

B—His relations with the general public to whom he sells and amongst whom he is the medium of distribution.

C—His relations with the State and the various Public Authorities who exercise control over such matters as hours of business, building, sanitation, escape in case of fire, transport, rating, and a large number of other matters.

Class II represents a variety of enactments designed, or supposed to be designed, mainly to safeguard the general well-being of the employes.

With regard to Class I, sub-headings A and B, I think that although there are still many anomalies, and hard cases occur, on the whole the Statute Law is reasonably clear and, at the same time, fair and effective.

With regard to sub-heading C, many traders are of opinion that legislature has, in some respects, gone farther than is essential, and that as regards Class II some of the legislation affecting employes is unduly irksome to the employer without being correspondingly beneficial to the employé.

I think the most important Statute falling within Class I, sub-headings A and B above, is the Sale of Goods Act 1893. It is a masterly codification of the whole accumulation of Common Law on the subject of sale of goods, and regulates the relations of buyer and seller in connection with every transaction of sale of

goods, wholesale or retail. It is obviously impossible to attempt any detailed examination of its provisions. One or two outstanding provisions may, however, be referred to, for instance, the definition of contract of sale, which is a "contract whereby the seller transfers or agrees to transfer to the buyer the property in goods for a money consideration called the price."

Any right, duty, or liability which may arise by implication of law may be negatived or varied by usage (*i.e.* custom of the trade) if that usage is such as to bind both parties. Then there is the provision as to the sale of goods of the value of £10 or upwards re-enacted from the old Statute of Frauds of Charles II. Its provisions have been the subject of endless litigation and questions as to its construction occur almost every day. This provision, which forms Section 3 of the Act, is—

A contract for the sale of any goods of the value of £10 or upwards is not enforceable by action unless (a) the buyer accepts part of the goods, (b) gives something in earnest to bind the bargain, (c) or in part payment—or unless some note or memorandum in writing of the contract is made and signed by the party to be charged or his agent in that behalf.

There is a huge body of law as to what constitutes "acceptance" and what is a sufficient note or memorandum within the meaning of the section, but in passing I might perhaps refer to the rather curious expression "gives something in earnest to bind the contract," and Section 4 provides that "earnest" means a coin or something valuable given by a buyer to signify the conclusion of the bargain. A ring may be given or a coin, but the thing must be "given." It was held in a case decided in 1817 that the operation of "striking a bargain," that is to say drawing a coin across the hand of the seller and taking it back, is insufficient. The doctrine of *caveat emptor* (let the purchaser beware) is definitely recognised by the Act, but is subject to so many exceptions and qualifications that it has been said that whilst the general rule is *caveat emptor*, it has become in reality largely the exception, at any rate as regards quality and fitness. For instance, when the buyer makes known to the seller the purpose for which the goods are required so as to show that the buyer relies on the seller's skill or judgment, and the goods are of a description which it is in the course of the seller's business to supply, there is an implied condition that the goods shall be reasonably fit for such purpose.

A question which often arises is whether or not the property in the goods, the subject of a sale, has or has not actually passed to the buyer. It is important in many aspects, both as affecting the position of the storekeeper in his relations with the wholesaler, and to a less extent with his customers—particularly in case of bankruptcy or insolvency, or the like, and difficulties sometimes arise in case of goods sent on approval or subject to payment C.O.D., and possession of which is obtained by the customer either by accident or design under circumstances which make it desirable that the tradesman should be able to establish that the actual property had not passed, and that he is entitled to return of the goods in specie.

A familiar instance of this is when a transaction is thought to be risky and a messenger is sent with instructions to obtain the money in exchange for the goods, but the customer having got the goods into his, or her, physical possession, declines to hand them back and says the money will be sent on or makes some other excuse for not complying strictly with the bargain.

There may be very extreme cases in which the circumstances may amount to the criminal offence of larceny by a trick and, on the other hand, it may be fairly clear that there has been a waiver of the original arrangement, and the transaction amounts to an out-and-out sale and delivery, for which the only remedy is to sue for the price, but there are a number of intermediate cases where guidance as to the legal position is provided by the Statute in question.

All the effects of sale as regards both buyer and seller, the seller's right to recover the price, time and mode of payment, right of unpaid sellers against the goods, damages for non-acceptance, sale or return (appro.), sale in *market overt*, and a variety of other matters are dealt with, and in general the Act may be said to make provision for most questions which are likely to arise out of the daily transactions of the retail distribution of goods.

I have just referred to the expression "*market overt*." The Common Law on this subject in course of time became well settled, and the Sale of Goods Act, 1893, adopted and reproduced the rule of the Common Law, which is, in effect, that where goods (other than goods belonging to the Crown) are sold in *market overt*, according to the usage of the market, the buyer acquires a good title to the goods although the seller was not really the owner of them. *Market overt*, or open market, is defined by the act—or rather the conditions—under which the goods are sold and, in effect, it comes to this that the place where the goods are sold must be a public or legally constituted market or fair; and the whole transaction must be begun and concluded openly in the market or fair.

Besides the exception of the goods of the Crown, there is another exception, and that is where goods have been stolen and the offender is prosecuted to conviction. The property in the stolen goods in these circumstances reverts in the person who was their owner and he is entitled to recover them notwithstanding any intermediate dealing with them, whether by sale in *market overt* or otherwise. Unless goods are sold in *market overt* the purchaser cannot retain them against the true owner.

By the custom of London, it has been recognised, from time immemorial, that a shop within the City of London is *market overt* between sunrise and sunset, except on Sundays and holidays. This custom was considered very carefully in a case in the year 1892. In that case pearls had been stolen from a society lady and sold to certain well-known jewellers at their establishment in the City, and on discovering the facts, she sued the jewellers for the return of her property; they contended that their shop being *market overt* within the meaning of the custom of the City and no prosecution having taken place they were entitled to keep the goods. Unfortunately for them, however, it appeared that the purchase took place *not* in the shop itself but in a showroom above their shop. The person who brought the jewellery for sale explained her business, and was thereupon taken behind the counter and into an upper room where the purchase by the defendants was effected, and this little piece of courtesy on the part of the purchasers put them out of court, it being held that whilst the shop itself, being in the City of London, was *market overt*, the showroom in which the sale actually took place was not within that description.

In the early part of the nineteenth century, public attention was much exercised with regard to alleged abuses arising out of the payment of wages wholly or partly in kind, and in 1831 was passed the Truck Act. Wharton's Law Lexicon describes the truck system as "the payment of wages in goods instead of money and that the plan has been for masters to establish warehouses or shops and the workmen in their employ have either had their wages accounted for to them by supplies of goods from such depots without receiving any money or they have had the money given to them with an express understanding that they were to resort to the warehouses or shops of their masters for the articles of which they stood in need."

By the joint effect of the Truck Act 1831, and the Truck Amendment Act 1887, the entire amount of wages earned by, or payable to, any workman must be actually paid to him in current coin of the realm, and any payment by delivery of goods, or otherwise than in current coin of the realm, is illegal, null, and void.

There have been numerous decisions as to the employés falling within the above description, but I cannot find that there has been any decision with regard

to drapers' assistants. Clearly, however, the Acts apply to those who are engaged in productive work.

Subject to certain conditions, involving either a contract signed by the workmen or a notice being kept constantly affixed in a place open to the workmen, certain exceptions to the rule regarding deductions from wages have been made, including fuel, medicine or medical attendance, materials, victuals (dressed or prepared under the employer's roof and there consumed by workmen), fines, damage to goods, machines, etc.

The Truck Act 1896, is the Act which sets out the conditions under which fines may be imposed, deductions may be made in respect of damaged goods, or in respect of materials. All these are dependent upon there being a contract, the terms of which are contained in a *notice* kept constantly affixed open to the workmen, in such a position as to be easily seen, read, and copied, or, in a contract, signed by the workmen.

With regard to fines, these are dealt with in Section 1, and the conditions, in addition to those relating to the exhibition of the contract, are that it must specify the acts or omissions in respect of which the fine may be imposed, the amount of the fine or particulars from which that amount may be ascertained, that the fine is imposed in respect of some act or omission which causes damage or loss to the employer, or interruption or hindrance to his business, and the amount of the fine is fair and reasonable, having regard to all the circumstances of the case.

I have referred somewhat at length to this particular section because it is provided that this section shall apply in the case of a *shop assistant* in like manner as it applies in the case of a workman.

Another interesting and important Statute is the Merchandise Marks Act 1887, with its various amendments, culminating in the Merchandise Marks Act 1926.

Prior to the passing of the Act of 1887, that is to say, at Common Law, to copy a trade mark or wrapper for goods was not forgery and, unless the matter could be brought within the Criminal Law, the injured person was without remedy, but by the Merchandise Marks Act 1887, every person is guilty of a misdemeanour who, amongst other things, applies any false description to goods. The punishment is very severe, the maximum being two years hard labour or a fine, or both, and in addition to this, a person is guilty of a misdemeanour who sells or exposes for, or has in his possession for, sale or any purpose of trade any goods or things to which a false trade description is applied. In the latter case, however, he is entitled to relief if he proves that having taken all reasonable precautions against committing offences he had no reason to suspect the genuineness of the description, and that on demand made by the prosecutor he gave all information in his power with respect to the person from whom he obtained such goods.

By the Merchandise Marks Act 1926, it is not lawful to sell or expose for sale, advertise, or distribute in the United Kingdom any imported goods to which the name or trade mark of any manufacturer or the name of any place or district in the United Kingdom is applied, unless accompanied by indication of origin, that is by giving conspicuously the word "foreign" or Empire, or the country of manufacture or production. There are certain exceptions relating to coverings, labels or reels for manufactured goods, and blends or mixtures. The sale in the United Kingdom of certain imported goods, unless they bear an indication of origin, may be prohibited by Order in Council. Various Orders have been made which are daily the subject of consideration in connection with imported goods.

By the Irish Hand Loom Weavers Act 1909, Irish woven linen damask, cambric, or diaper, is to be marked with specified words, and there are numerous

Acts relating to the stamping of Irish linen, going back as far as the Linen (Trades Mark) Acts 1743 and 1744.

It has no doubt been remarked that in the case of certain goods, such as silks, jewellery, furs, or hand-made lace, these goods are always dealt with in the dispatch department as on the special footing of insurable goods. This is due to the provisions of the Carriers Act 1830, which was passed with the primary object of protecting common carriers from the great risk which they ran under the Common Law in carrying articles of great value in a small compass. With regard to lost property, the carrier attempted to protect himself by posting up notices limiting his liability, but there was great difficulty in fixing consignors with knowledge of such notices. Accordingly, the Act provides that no common carrier by land shall be liable for the loss of or injury to any article or property of certain specified descriptions, including the above, where the value of such property shall exceed £10, unless at the time of the delivery of the package at the carrier's office or to his servant, the value and nature of such articles or property shall have been declared by the person delivering the package, and an increased charge above the ordinary carriage paid or agreed to be paid, and the carrier is entitled, provided he affixed in a conspicuous part of his office or receiving house, a legible notice stating the increased rate of charge, to demand such increased charge.

Marks containing representations of the Royal Arms or colourable imitations thereof, or British Royal Crowns or National Flags, or the word "Royal" or anything giving the impression that the applicant has "Royal" patronage, may not be registered as a trade mark, and, in addition, the Registrar of Trade Marks has power to refuse marks containing representations of the Sovereign or any member of the Royal Family. There is, however, I believe, an exception with regard to certain very old marks.

The wrongful use of the Royal Arms is punishable by a fine of £20 or an injunction can be obtained. In effect, no one but those who personally hold the Royal Warrant can use the Royal Arms. Before the formation of the Royal Warrant Holders' Association, a good deal of misapprehension existed on this subject, it being thought in many quarters that the fact that a member of the Royal Family was a regular or even a casual customer was sufficient to authorise the use of the Royal Arms. This Association, however, which has now been in existence for many years, has by means of publicity and by instituting or threatening proceedings in certain cases, made the position tolerably clear, and few cases of misuse of the Royal Arms now occur.

Under the Geneva Convention Act 1931, a person may not without the authority of the Army Council use for the purposes of his trade or business the heraldic emblem of the red cross on a white ground, or the words "Red Cross" or "Geneva Cross," but there is a limitation in favour of the proprietor of a trade mark registered before the passing of the Act.

The question of giving change is one as to which, of course, no difficulty arises in practice, but the legal aspect is interesting. This is regulated by the law of legal tender and the material Statutes are the Bank of England Act 1833, the Coinage Acts of 1870 and 1891, and the Currency and Bank Notes Act 1928. First of all, it is abundantly clear that no one is bound to give change. It is the duty, which can legally be insisted on, of every customer to provide himself with the exact sum required and tender that sum in payment neither more nor less, and to be legally valid a tender of payment of money unless made in authorised paper currency, must be made in coin issued by the Mint. Such coins are legal tender (1) in the case of gold coins, as also Bank of England Notes, for any amount; (2) in case of silver, coins for an amount not exceeding 40s.; (3) in case of bronze coins for an amount not exceeding 1s. So if some cranky person proposes to pay your account of £5 in threepenny bits, or of 5s. in farthings, you

are at liberty to decline to take it, although, in practice, you would probably not do so. I have heard it suggested that if a larger sum than that due is tendered the recipient is entitled to keep it, but I do not think this would be upheld to-day, but tender of a larger amount than that due with a demand for change has over and over again been held to be bad.

Attention has been directed by a recent decision in *The Times* to the position of the employer in giving a reference or character to his employé. This is not strictly a matter of legislation, although, of course, the Statutes relating to libel and slander may have application to the subject under certain circumstances. However, it is a matter of interest and not wholly of common knowledge, and, therefore, I propose to include one or two observations on this point.

First, a master is under no duty either to give a servant a written testimonial as to character on his leaving employment or to answer inquiries of persons wishing to take him into their service, and the servant has, therefore, no remedy in the event of the master refusing to do so, however great the consequent injury may be.

If the master chooses to make a statement as to the servant's character and the servant, in consequence, suffers damage either by being unable to obtain employment or by being dismissed from employment which he may have obtained his right of action depends solely upon whether the statement is actionable as being defamatory. If, however, the statement is true, no action will lie against the master, and even though it is untrue it is a privileged communication, since it is of importance to the public that characters of servants should be readily given, and there is, therefore, a presumption that it is made *bona fide*. Privilege, however, may be rebutted upon proof of express malice.

In these circumstances the greatest care should be exercised in dealing with the question of references and statements made in regard to the character of any employé as, in the event of statements made on the faith of hearsay turning out to be untrue, the employer's only defence to an action is to rely upon privilege, which it is not always easy to substantiate. It has, however, been held that privilege attaches not only to communications made to persons who are thinking of engaging a servant or have already taken him into their service, but extends also to communications made to his previous employers or to an employment agency through which he may have been procured. Whether statements made to other persons are or are not privileged must be determined by the circumstances of each particular case.

A recent case in *The Times* emphasises the necessity of exercising extreme care when taking up a reference. In that case the defendants were watch and clock makers, and advertised for a clock winder. A man answered the advertisement, gave reference to a jeweller in a provincial town which was taken up by post and was engaged. Within a fortnight it was alleged, the employé, having been sent to the house of a customer to wind the clocks, stole jewellery to the value of over £300 belonging to the customer. It then turned out that the man had given a false name, that the address which he had given was an accommodation address, there was no jeweller of the name given as a reference at the place indicated, the address being one of a row of cottages, and it was alleged that the man had served several terms of imprisonment. In these circumstances the customer sued the firm for the value of the jewellery, alleging that they were under a duty to take all reasonable care that the clock winder whose duties took him into the houses of people of rank and means was a dependable person, and that they had not done so, and were accordingly guilty of negligence. The Court held that they had not taken sufficient care in making inquiry about the man and were liable to make good the loss.

A discussion followed the reading of the above paper and the meeting ended in a hearty vote of thanks to Alderman Brooks.

Midlands Section

Meeting in the University College, Shakespeare Street, Nottingham, on Thursday, 17th November 1932; Mr. P. A. Bentley presiding.

DEVELOPMENTS IN KNITTING MACHINES AND PROCESSES

In a lecture on the above-named subject given by Professor W. Davis, reference was made to the inter-action which takes place between the main fibres used in knitted goods. At one time cotton gained ascendancy for a particular branch, at another time wool or rayon. Cotton had recently scored an enormous advantage over wool in the production of interlock fabrics, which were being made in increasing quantity by many manufacturers in the Midlands. The British spinner had scored in this particular type of single yarn which was mainly produced from Peruvian cotton in counts from 40's to 60's single. After much experiment, the spinner had arrived at the ideal yarn for this particular purpose. There was little to equal the handle of the interlock fabric as produced to-day on the circular knitting machine. Its great merit was that there was no wrong side to it. This made it very smooth to wear next the skin, and also increased its absorbency. When cut up into garments this particular texture was extremely stable at the edges. It did not curl and could therefore be treated very efficiently in sewing and seaming.

The knitting industry, continued the lecturer, was at present following the trend in other branches of textiles, and using lustrous yarns such as silk and rayon with very high degrees of twist, to give crêpe effects and to produce what was termed a sheer lustre. This was giving considerable difficulty in manufacturing routine, as these yarns tended to kink and snarl on the needles. Stockings also very often showed variable lustre from point to point. The extra twist did not appear to give any difficulty with regard to a longer period of wear. The same tendency was to be noticed in rayon yarns, where high twist 20 to 30 turns per inch were now being used instead of the orthodox $2\frac{1}{2}$ turns per inch. To obscure the lustre of such materials was perhaps proving of an advantage to the lisle cotton stocking trade. Wearers were now adopting those articles in increasing quantities because they were nearly equal in point of lustre with the new dim-lustre rayon articles. On the other hand, the bathing costume trade had become of very great importance to the knitting industry, and, in this branch, wool had definitely displaced cotton for the great majority of articles. The wool used was of the cross-bred variety and produced in single counts to be knitted into one-and-one fabrics. The advantage of wool as compared with cotton for this purpose was that it wetted out more slowly and did not chill the bather as cotton garments did. There was one exception to this, and that was the bathing articles used for racing purposes. It was found that the wetted garment in wool caused a larger drag on the competitor as compared with the cotton article. Cross-bred wool had also shown very solid advantages in such articles as gymnastic hose and the thicker types of footwear required for the more strenuous walking exercises and various sports.

Stouter wools gave less felting and also provided a greater bulk of material to act as a cushioning agent in motions having the character of a thrust. The cross-bred wool used bordered on the Botany type. One of the most active branches of the spinning industry at the moment was that concerned with the provision of yarns for hand knitting. This was a national craze, and spinners had vied with each other in altering their merchandising methods to provide such thick yarns in a suitable form for convenient use by the home knitter. These were being developed very largely in an open character of stitch so that although the yarns were thick, the resulting texture was light in weight.

The lecturer also referred to the opportunity which the British spinner had obtained during the past year in replacing many types of yarns previously imported. Mule spun yarn produced on the Continent had hitherto been almost

indispensable for certain branches of the knitting industry. Owing to reduced supplies of such yarns, the British spinner had received encouragement. To produce yarns having that open character required for many purposes of knitting, frame spun yarn had hitherto provided a yarn which in general was too tight in character and possessed meagre cover for the interstices of the loops. The builders of such frames, however, had recently made notable improvements in construction, and it could be said that the frame spun yarn was making steady headway in all branches of the knitting industry.

In regard to rayon, the usual counts had proved too dense for purposes of knitwear, and there was a growing demand for types of rayon which were more bulky in handle, such as the aerated yarns. Staple fibre yarn was also used to an increasing extent in knitted productions, because fabrics made from such yarns were not so liable to ladder. They also exerted a better grip during wear, being less slippery than the usual types. Lilienfeld yarn, although it possessed a high degree of tensile strength, had so far proved unsuitable for use on knitting machines, owing to its lack of resilience under the pressure exerted by sinkers and needles. Recently there had been persistent production of even finer gauges in all branches of the knitting industry, and the slogan seemed to be "Warmth without Weight." Hitherto, the latch needle machine had not been able to handle very fine gauges, owing to the difficulty of obtaining a needle slender enough possessing adequate strength. In this respect, considerable progress was to be noted, and a new latch needle had been produced so that 31 of them could be arranged per inch in a circular stocking machine. This came very near to the limit possible by the spring needle, which in the past had held the monopoly in fine gauge fabrics.

A discussion and a vote of thanks to the speaker terminated an interesting meeting.

NOTES AND NOTICES

Institute Employment Register

The following announcements are taken from entries in our Register of Members whose services are on offer. Employers may obtain full particulars on application.

- No. 93—Mill or departmental management; age 23 years; practical experience in mill organisation and control; secondary education; City and G. Full Tech. Cert. in Cotton Spinning.
- No. 94—Draughtsman, technical assistant, or full-time teacher; age 29 years; six years' as evening teacher and 15 years' experience as textile draughtsman; A.T.I., Nat. Cert. in Mechanical Engineering.
- No. 95—Chemist (Research or Works) in artificial silk or general textiles; age 33 years; three years' Chief Chemist and three years' Technical Manager and Chief Chemist; Ph.D., M.Sc., B.Sc., F.I.C.
- No. 96—Secretarial work in any branch of textile industry; age 29 years; 13 years' Asst. Secretary; secondary education; A.T.I. and City and G. Full Tech. Cert. in Cotton Spinning.
- No. 97—Asst. Manager or Asst. Salesman; age 27 years; experience in general mill office and as cloth tester and costing clerk; secondary education; A.T.I., A.M.C.T.
- No. 98—Draughtsman; experience in mill planning and mill construction; seeks post as cotton yarn and cloth testing clerk, or in research work; age 26 years; secondary education; A.T.I.
- No. 99—Spinning Master or Asst. to Manager; age 29 years; 15 years' practical experience; A.T.I.

Textile Institute Diplomas

Election to Associateship has been completed as follows since the appearance of the previous list (February issue of this *Journal*)—

ASSOCIATESHIP

OSBORNE, George Gordon (Massachusetts, U.S.A.)

Institute Membership

At the March meeting of the Council, the following were elected to membership of the Institute: *Ordinary*—C. Ashworth, c/o The China Finishing and Printing Co. Ltd., P.O. Box 1199, Shanghai, China (Spinning and Weaving Mill Manager); A. Brooke, 108 Birkby Hall Road, Huddersfield (Assistant Manager, Middlemost Bros. & Co. Ltd., Huddersfield); D. A. Derrett-Smith, "Rosthern," Lambeg, Lisburn, Co. Antrim (First Assistant in Chemistry Department, Linen Industry Research Association); J. Galloway, 17 Barnstead Avenue, Withington, Manchester (Shippers' Greyman); H. Gruter, c/o S. A. Torcitura di Borgomanero, Via Solferino 19, Milan, Italy (Managing Director); H. Hammond, 91 Legrams Terrace, Legrams Lane, Bradford, Yorkshire (Loom Tuner and Part-time Instructor in Weaving Mechanism); V. L. Knowles, c/o Messrs. W. R. Bland & Co., 47 Lime Street, London, E.C.3 (Textile Engineer); J. A. Matthew, 165 Sandown Road, Knock, Belfast (Physicist, Head of Spinning and Weaving Department, Linen Industry Research Association); A. Scholes, 6 Brenka Avenue, Aintree, Liverpool (Textile Chemist, British Enka Artificial Silk Co. Ltd.). *Junior*—Wm. Forsyth, 20 Vicars Hall Lane, Boothstown, nr. Manchester (Loom Overlooker, Robert Farnworth Ltd., Boothstown); Wm. E. Kyle, "Ferndene," Hamilton Drive, The Park, Nottingham (Full-time Textile Student).

REVIEWS

Hosiery Cost Accounts. By Stephen F. Russell. Published by Sir Isaac Pitman and Sons Ltd. (168 pp. and index, price 10s. 6d. net).

This book will provide much valuable assistance in costing to the manufacturer of hosiery, the author dealing with phases of the subject which have hitherto been neglected in the literature on the subject. This volume is written from the viewpoint of the expert accountant and the subject matter related to practice in seamless and full-fashioned footwear, the author being a works accountant with a firm in this branch. Fundamental principles of hosiery book-keeping and accountancy are emphasised throughout and the careful student will find much which he can apply to any branch of knitted goods manufacture. A valuable feature is the number of forms given relating to all departments for the correct recording of statistical data relating to yarn stocks, goods at the various stages of manufacturing routine, and records of sub-standard hosiery.

The chapters relating to the correct allocation of overhead expenses, factory, warehouse, and general, will repay careful study and reliable methods are clearly illustrated by numerous practical examples. A number of examples of final cost summaries relating to different weights of hose are given, divided into the following sections—(1) Yarns of every sort used in the article, with proper allowances for waste and what is termed adjustment. Then follow in (2) departmental operation and process costs, including dyeing, boarding, folding, and boxing. These are given at different figures based on piece rates and not subject to cost-of-living bonus additions, as in common practice in the Midland hosiery towns. Then come in (3) the works office and general office expenses as a percentage of these operation costs. In the general overhead, and stated as a figure per dozen, are warehouse, despatch, sales, advertising and distributing costs. Then follows an allowance under the head of administration. The book is attractively written in a lively style and forms a valuable addition to the literature relating to the knitting industry. Mr. F. R. M. de Paula, late Professor of Accountancy, contributes the foreword. W.D.

Rubber Latex. By Henry P. Stevens and W. H. Stevens. Issued by The Rubber Growers' Association Inc., Eastcheap, London, EC3 (156 pp.).

The application of rubber to textiles in the past has been a special branch of the rubber industry rather than of the textile industry. The necessity for employing the rubber dissolved in inflammable and somewhat objectionable solvents and the difficult method of vulcanisation have combined to keep rubber proofing and finishing apart from ordinary textile processes.

The advent of rubber latex as a commercial raw material together with the production of vulcanisation accelerators has however brought the treatment of

cloth with rubber within the technique of the ordinary finisher, and latex is finding more and more use in the textile industry.

This book therefore will be of great interest to the textile manufacturer. It contains first-hand information about the production and properties of rubber latex and its manifold applications with a frank exposition of the practical difficulties and pitfalls. If the information on the use of latex in textiles is found to be meagre, it must be remembered that the subject is still in its infancy.

The latter half of the book is devoted to a very useful bibliography of patents on rubber latex preceded by some sane remarks on patents in general. The book will form an excellent manual for anyone wishing to pursue the subject thoroughly.

R. G.

Occupational Diseases. By Rosamond W. Goldberg. Published by the Columbia University Press, New York—London Agents, P. S. King & Son, Westminster, S.W.1. (253 pp. Bibliography and Index. Price, 22s. 6d. net.)

This volume is No. 345 of a series of publications edited by the Faculty of Political Science of Columbia University, U.S.A., under the group title of "Studies in History, Economics and Public Law." It has particular reference of course to conditions in the United States, but by analogy is of interest to those who are concerned at the prevalence of occupational diseases, and in their prevention or cure. The book reviews the various hazards to which many workers are being regularly exposed and attempts to determine whether a system of health insurance can be applied to meet the large number of cases of occupational diseases and industrial poisoning. In dealing with systems of health insurance, Dr. Goldberg first surveys those of Germany and Great Britain, drawing a comparison between the two systems, and then briefly refers to those of other countries, such as France, Japan and Russia. She then surveys health insurance in the United States, dealing with attempts and early essays in some form of health or sickness insurance by voluntary effort, single corporations, or States. Reference is made to the failure of voluntary insurance and to the agitation for a Compulsory State Scheme, with particulars of legislative attempts placed before the Federal Government. Finally, a summary of reasons for the need of compulsory health or sickness insurance is given, and the conclusions drawn that such insurance provides a powerful stimulus to the adoption of health-saving devices and methods of operation; makes decided gains in the elimination of certain hazardous industrial processes and the prohibition of the use of certain deleterious substances; improves the health of the workers; reduces mortality and vitally affects the everyday activities of the population.

Among the hazards reviewed are those in which dusts occur, such as in the cotton, flax, hat, and carpet industries; those in which toxic gases, vapours and fumes are encountered, such as the rayon and dyestuffs industries; and such diseases as anthrax, dermatitis, and cancer. Altogether the book summarises a mass of information admirably and, coupled with a useful and wide-flung bibliography, is a welcome addition to the literature of public health and industrial welfare.

T.

PUBLICATIONS RECEIVED AND ADDED TO THE INSTITUTE LIBRARY

Hints on Automatic Weaving: A Handbook for Automatic Loom Users. By M. Proctor-Greg. Published by the British Northrop Loom Company Limited, Blackburn. (106 pp. and Index. Price, 2s. 6d. net.)

This booklet describes in Part I, the Northrop Automatic Loom, giving details and drawings of the various parts and attachments. Part II describes the Northrop system, which concerns itself with the number of looms per weaver; the auxiliary labour in the shed; payment by the pick instead of by the piece; and continuous running. Notes are given on preparation, the warp, the weft, re-winding, lighting, power requirements and humidification.

Report of the British Association for the Advancement of Science, York, 1932.

This report contains the presidential address, by Sir Alfred Ewing ("An Engineer's Outlook"); the Section presidential addresses and brief abstracts of many of the papers read before the various sections. Reference has already been made in this *Journal** to papers thought to be of interest to members of the

**J. Text. Inst.*, 1932, P288.

Institute. Of these papers that by Professor R. G. White, on "Sheep-Farming: a distinctive feature of British Agriculture," appears in full (pp. 229-256), and those by S. G. Barker and C. G. Winson; J. Firth and F. Buckingham; W. N. Haworth; H. Staudinger; E. L. Hirst; H. Mark; W. T. Astbury; W. B. Crump; H. C. K. Henderson; G. C. Allen; R. F. Wilson; W. O'D. Pierce; W. C. Miller; A. H. H. Fraser; and S. E. J. Best appeared in abstract.

Skinner's Cotton Trade Directory of the World, 1932-33. Published by Thomas Skinner & Co., London, Manchester, Bradford, New York and Montreal. (888 pages. 20s. net.)

Contains a useful addition in the form of an index of all firms included in the Directory. A big reduction in size has been effected, mainly by the elimination of details under the Foreign Spinners and Manufacturers' Section, and by compounding the Bleachers, Dyers and Finishers' Section under Finishing. This is a sensible step, as it makes—with the index above—searching much less tedious. The general result is an easily handled volume.

Kingston's Sterling-Dollar Price Conversion Tables. Published by Kingston's Translations Institute, London. (Price, 2s. 7d. post free.)

These tables allow of conversions from Sterling per cwt. to Dollars per 100 lb., or from Sterling per Imperial ton to Dollars per 2,000 lb., at exchanges \$3.00 to \$3.95 to £, rising by single cents and by eighths of a cent.

British and Dominion Textile Industry (excluding Lancashire and Yorkshire), 1933. Published by John Worrall Ltd., Oldham. (319 pp. Price, 12s. 6d. post free; abroad 14s. 6d. net.)

The 43rd edition of this well-known directory, which covers the United Kingdom, except Lancashire and Yorkshire, the Irish Free State, and the Dominions of Australia, Canada, New Zealand and Tasmania. This is a very useful and handy work of reference. Maps would enhance its value.

"The Drapers' Organiser." Annual Directory of Trade Marks and Trade Names, including Shopfitting and Display Section, 1933. Published by the National Trade Press Ltd., London.

A useful compilation with introductory information on the choice and registration of trade marks and names. It would be definitely improved were the advertisements to be removed from the text and grouped together.

GENERAL ITEM

THE WORLD FLAX CROP 1932 AND MARKET POSITION

The following Abstract has been compiled from three sources—

- (1) the *International Review of Agriculture*, 1932, 23, 613-614;
- (2) the *Deutsch Leinen Industrielle*, of 24th November, 1st December, and 31st December 1932; and 21st January 1933; and
- (3) *Het Vlas*, of 6th December 1932; 3rd January, 10th January, and 31st January 1933.

The shrinkage in the cultivation of flax, which has marked all seasons since 1928/1929, continued in all the important producing countries, except the Soviet Union, in 1932. The *International Review of Agriculture* holds the view that the average increase in the U.S.S.R. more than compensates for the decrease in acreage outside Russia, though this does not appear to be the general opinion. Yield per acre and quality of production are factors quite apart from mere acreage and are referred to specifically below.

Specified decreases in acreage are quoted [see (2) above] as follows—

In the Netherlands	... ..	not less than	70%	decrease
In Belgium	... ..		42%	"
In Germany	... ..		32%	"
In Czecho-Slovakia	... ..		20%	"
In Northern Ireland	... ..		18%	"
In France	... ..	about	2%	"
In Estonia, Latvia, and Lithuania	... ..	average	26%	"

Though production figures are not available for all countries, those to hand indicate (outside Russia) about an average yield per acre. In most of the European

flax producing countries the weather conditions in August were favourable to the crop and to harvesting operations. [See (1) above.]

In the U.S.S.R. the crop had already been harvested by the 1st of September and according to the *International Review* [See (1) above], this was affected at the first yellow stage of ripening, a guarantee of good quality fibre. Russian estimates indicate that 2,510,000 hectares of fibre flax (Dolgunez) were sown in Soviet Russia in 1932, but official figures for the 1932 crop, for comparison with the 537,000 tons yield in 1931, are not yet published. But in Russia, the "yield" figures available month by month have led to the realisation that an increase, even if only gradual, in yield per hectare is of much more importance than mechanical increase in acreage. The scientific institutes are making great efforts towards this end, and *Het Vlas* (3) records that chairmen of village councils, directors of tractor and machine stations, as well as other officials, have been dismissed from the Communist party as a result of their failure to secure the production aimed at. An example is quoted (3) of the dismissal and arrest of the Board of the White Russian Flax Trust at Minsk, for reporting a 102% carrying out of "the plan," whereas the true figure was 50 per cent. *Pravda* is quoted as saying that "the quality of the fibre is quite inadequate. The battle for better flax production is not organised in any way." In addition, Russian flax cultivation has been hampered by the conditions of the roads which in many cases is "undescribable." [See (2) above.] For broad success in cultivation, implying high yields of good quality fibre, time will be necessary, as high yields are ultimately dependent upon soil conditions which, after a long period of bad agriculture, cannot immediately be changed. There are signs that the collective enterprises in Russia have succeeded in increasing their yield very considerably and offer a successful alternative to individual concerns which cannot, apparently, be coerced into becoming good farmers.

In France the practical result of the flax subsidy has been limited, so far as the 1932 crop is concerned, to preventing further defection from flax cultivation by agriculturists. Faced with a 66% reduction in acreage from 1930 to 1931 the French Government tabled a subsidy of 60 million francs per year for a period of six years. Premiums were to be paid on a unit weight of processed fibre, and it was the intention to produce the effect of a guaranteed price of 10.50 francs per kilo to producers of flax of a given quality. This corresponds to a valorisation of approximately £86 (gold) per ton, which may be compared with the current quotation [See (2)] of £36 (gold) for B.K.K.O. The comparative failure of the scheme appears to be due to administrative difficulties arising in making the calculations on the unit of fibre and recently Department orders have been made to pay premiums at so much per hectare.

Prices at Ghent and Courtrai have risen from £35—£35 10s. od. (gold) at the beginning of December to between £38 10s. od. and £39 (gold) in mid-January. Russian deliveries of restricted quantities, and at these prices, have been spread over four to five months, and Ghent spinners appear to have combined for a substantial part of these Soviet supplies. In Courtrai ordinary weft flaxes which were at 6.50 francs in December were selling at 7.50 francs in early January. Other standard sorts showed a lesser advance. Attempts to buy heavily at present prices were frustrated by inadequate supplies. Riga reports indicate, later, that the Soviet monopoly appear to make a good profit out of flax, paying £27 gold per ton, to which may be added overheads at £7, and selling at £40 per ton. At this price, sales of 150-200 tons for the month are reported in mid-January.

The above survey of acreage, yield, and quality of crops indicates a growing "flax weariness" outside Russia, which had already made its appearance in preceding years. Russian predominance in Eastern markets cannot, perhaps, be doubled, but internal conditions indicate that supplies for export are not only likely to be restricted in volume, but inferior in quality, under which circumstances, such predominance must not be over-estimated. Despite good market reports, *Het Vlas* records the opinion that activity cannot be of long duration in view of the weakness of the cotton market. At the same time the world flax market is not over-supplied, and to that extent is healthy. The *Leinen-Industrielle*, on the other hand, takes the long view that the tendency towards restriction of cultivation conceals dangers which demand particular attention. I..

THE JOURNAL OF THE TEXTILE INSTITUTE

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PROCEEDINGS

Lancashire Section

Meetings of the Section on 10th December 1932, at the Athenæum, Manchester; on 17th January 1933, at Burnley; on the 27th January 1933, at Preston; on the 8th February 1933, at the Institute, Manchester; and on the 10th March 1933, at the Institute, Manchester.

On the 10th December, at the Manchester Athenæum, by invitation of the British Association of Managers of Textile Works, members attended a meeting addressed by Major W. Vernon (Fellow), who spoke on "**Indian Cotton from the field to the Sepoy's Uniform.**"* The lecturer dealt with developments since 1896, in which year he went to India. He gave statistics of increases in spindles and looms, and of cotton consumed, with import and export figures of cotton and piece goods. He described the efforts made to secure better-class cottons to enable yarns to be spun satisfactorily for the local weaving demands. A description was given of the efforts made to supply piece goods for Government contracts, and for such requirements as porters' uniforms and hospital sheets. Major Vernon also gave an account of developments in dyeing the goods so supplied and made special reference to the effect of the war and post-war political changes on the cotton textile industry of India.

A joint meeting with the Burnley Textile Society was held in the Mechanics' Institute, Burnley, on 17th January, when a paper was read by Mr. Enos Lees, of the Universal Winding Company, Manchester. His subject was "**Recent Developments in Winding and Warping,**" and he dealt first with the costs of the pre-weaving processes and the reasons for this. The lecturer next dealt with the clearing aspects of the winding process and its bearing upon the manufacture of saleable cloth. The lecture concluded with a survey of various machines and winding methods with statements as to their relative advantages.

At Preston in the Harris Technical Institute, on Friday, 27th January, Mr. W. Wilkinson (Fellow) delivered a lecture on "**Problems in Weaving.**" The lecturer dealt more particularly with problems in relation to the manufacture of high-grade fabrics and made reference to the development in demand for piece-goods either wholly of rayon or incorporating rayon yarns.

Lancashire Section members attended at the Institute in the number of nearly one hundred to hear a lecture by Mr. J. Tetlow, of Messrs. Platt Bros. & Co., of Oldham, on Wednesday, 8th February 1933. The subject was "**Recent Developments in Ring Spinning and Doubling Frames,**" and was illustrated by lantern slides. The lecturer first described the firm's recently developed ring-spinning frame which spun either warp or weft yarns in all spindle gauges upwards from

*A full abstract of Major Vernon's lecture appeared in the *Textile Weekly*, 30th December, 1932.—*Editor*.

2½ inches. He made special reference to high drafting, or higher-than-usual drafting, and for comparison purposes dealt with the older types of low-drafting rollers, showing that the coming of the smaller second lines of rollers was an obvious development, as was also the building-up of four lines of rollers.

Discussing correct winding tension, the lecturer pointed out that "whilst the trade was content with shorter lifts, the necessity for controlling the balloon was not so vital, and it was found that lifts up to 5½ inches were giving satisfactory results with a stationary lappet. With longer lifts above this point it became essential to obtain greater control of the winding yarn, and therefore on lifts 6 inches to 10 inches it was necessary to arrange for the correct application of moving lappets.

The lecturer next described various methods employed in the driving of spinning and doubling frames by individual motors, and instanced drive by variable speed motor; by Texrope; by chains; by gears; by belt with tension pulley; and by ropes. Referring to drive by variable speed motor, Mr. Tetlow pointed out the ease of control by one handle. Full advantage is to be taken of this control feature by slowing down the motor speed whilst the cop bottom was being built; immediately this is formed, the speed is increased until the lift approaches the top of the cop. At the top of the cop, the speed is again reduced to a rate approximating to that used at first. Speed is also varied during each rise and fall of the ring rail. The control is effected by means of dual cams operated from the lifting lever and heart shaft respectively, and coupled by levers to the control handle of the motor.

A new weft ring spinning frame was next illustrated and described and the lecturer pointed out that all angles present in the usual type of ring-frame between the traveller and the front roller have been eliminated. Therefore that length of yarn between lappet eye and front roller, which does not contain the full amount of twist passed forward by the traveller, is now twisted to the same extent as the remainder of the thread. This result was due, said Mr. Tetlow, to the fact that the twist is not checked by angular contact at any point. A definite vibration or balloon is set up both below and above the lappet eye, and this has the effect of "fulling" the yarn in the desired quantity. Regular twist is in the whole length of the yarn between the traveller and the front roller, and the usual weak place at the roller nip has been eliminated. The inclination of the roller stands on these machines was 45° and could be arranged for either long or low drafting.

In describing a long-lift ring-spinning frame, Mr. Tetlow pointed out that this machine had been designed to meet the requirements of the coarse yarn spinner and of the hosiery trade. Weights of yarn equalling 1 lb. per spindle were secured and these results in conjunction with a magazine doubling creel were proving useful and efficient. Lifts ranging from 8 inches to 10 inches, and rings from 2 inches to 3½ inches, were usual, and the spindles for carrying these large packages had been strengthened and balanced accordingly.

A compensating motion was described by the lecturer, which had been arranged so that full advantage could be taken of the ring diameter when spinning on paper tubes or tapered bobbins. The motion itself was a simple eccentric applied between the lifting lever and the rocker operating the lifting pillars or pokers, and was composed of a true radius working in conjunction with an adjustable eccentric. The action was merely that the chase of the cop was shortened by small increments, and that, therefore, the same amount of yarn was wound, lift for lift of the ring plate, but wound over a less chase, and in this way the desired parallel bobbin was secured.

Automatic cleaning arrangements were next discussed, and a special scavenger motion described which had been arranged so that the cleaning of the top boards and lappets was accomplished mechanically and at regular intervals. This

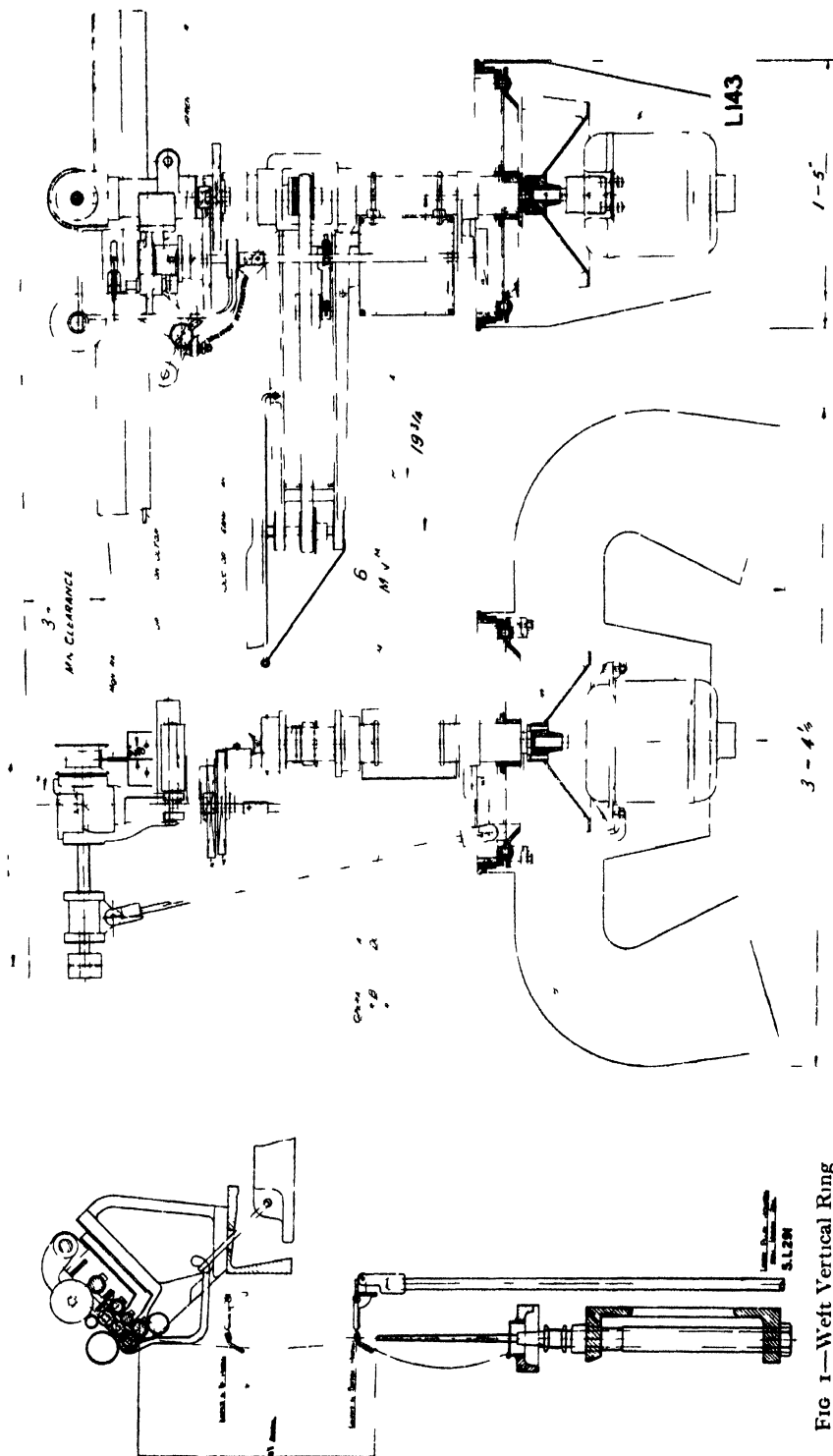


FIG 1—Weft Vertical Ring Spinning Frame

FIG 3—Automatic Travelling Cleaner

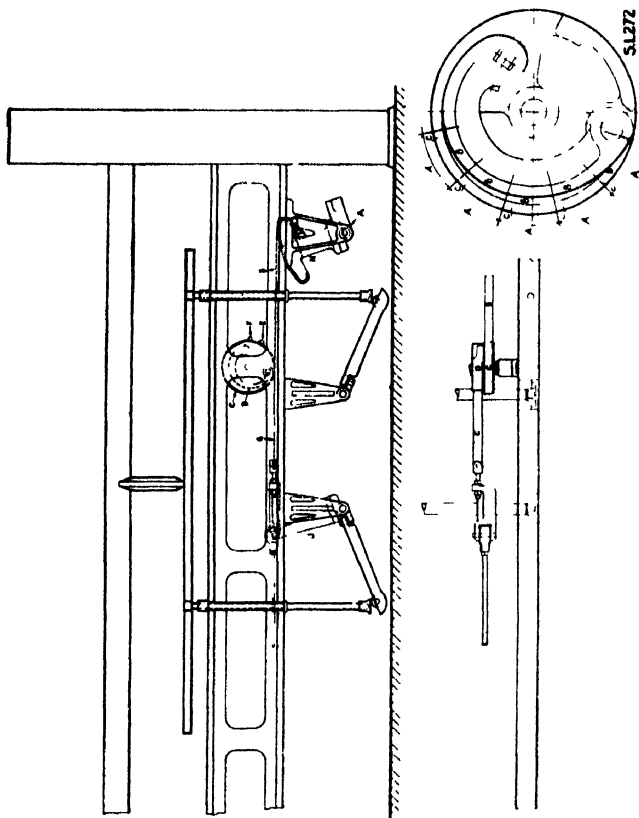


FIG. 2—Compensating Motion for Ring Spinning Frames

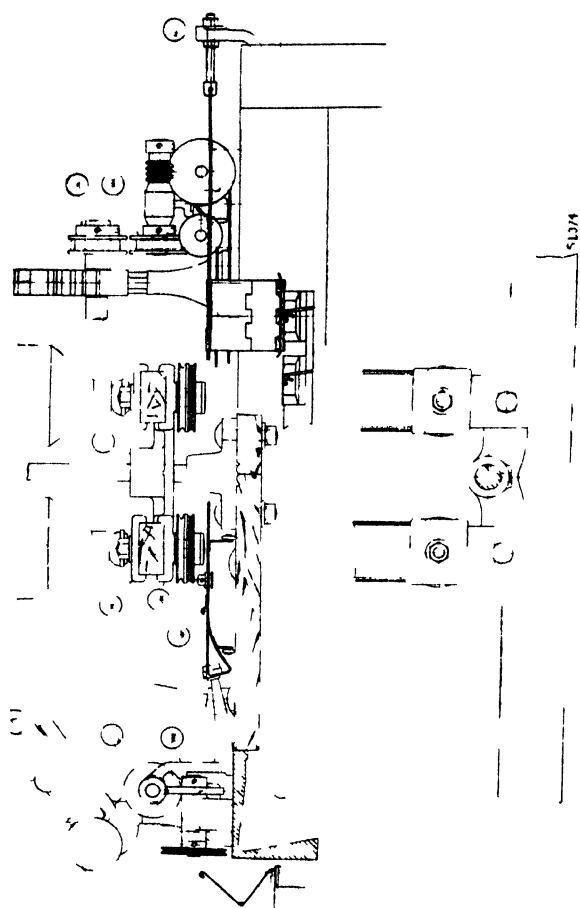


FIG. 4—Automatic Travelling Scavenger Motion

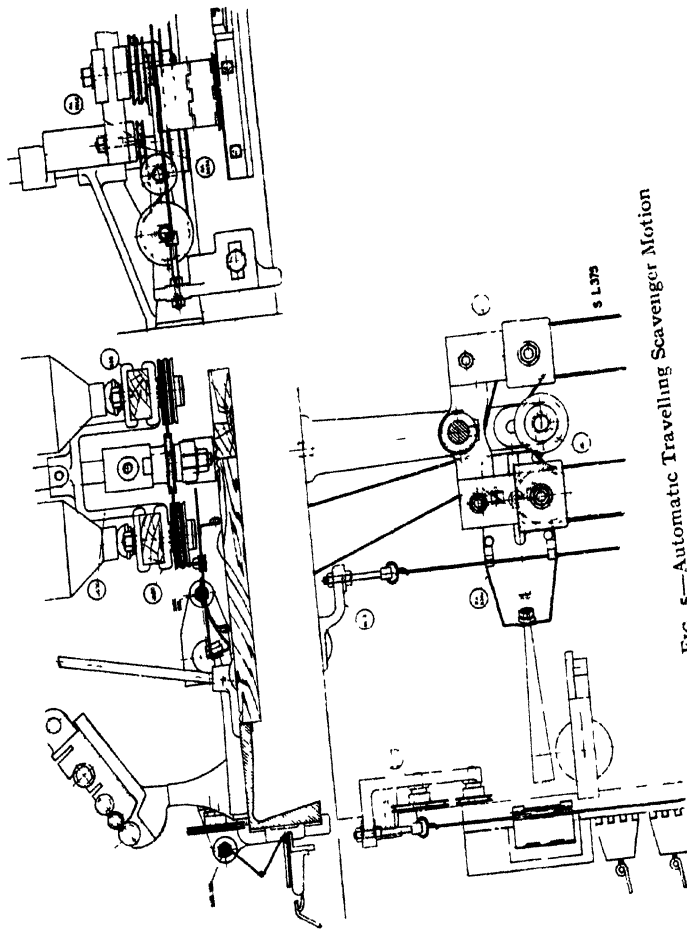


FIG. 5—Automatic Travelling Scavenger Motion

cleaner is fitted with hinges when applied in conjunction with lifting lappets, so as to remain in contact with the lappets at every part of the build. Another cleaning apparatus illustrated by the lecturer had been evolved to eliminate cleaning by hand the whole of the upper structure of the machines and exerts a cleaning action on all parts above the spindles. The device is a travelling blower carried on a monorail over the machines in the room. Its action is to blow any loose fibres downwards and to prevent their accumulation. The monorail acts as bearer for the electric power wires.

In reference to ring doubling, the lecturer described recent improvements on this type of machine and stated that to ensure a definite roller delivery two lines of bottom rollers and one line of top rollers, cradled between the two, were provided. The spiral yarn doubler illustrated had been devised to suit the fancy trades and was fitted for the production of speciality yarns such as are made on two rollers having a continuous delivery at different speeds or irregular and uneven delivery of one of the lines. An arrangement of delivery rollers for coarse cotton counts and for such materials as asbestos was also described. In place of the usual two lines of bottom rollers and one line of top rollers, we have merely two lines of bottom rollers spaced apart with small porcelain division pieces carried on a square bar between two rollers. This method gives a definite hold on the yarn and is a good preventative of corkscrew yarns.

The meeting at the Institute on Friday, 10th March 1933, was addressed by Mr. T. Wareing, of the Grecian Emery Works, Rochdale, on "**The History of Abrasives and the Evolution of Grinding.**" The Chairman, Mr. T. E. Mitchell, introduced the lecturer, who said—

To give a talk on abrasives and their uses is to introduce a subject which is capable of great extension. I propose, therefore, to give a brief account of the better-known abrasives and indicate their uses in relation to textiles. Most people are familiar with ordinary emery-cloth and glass-paper, but there are many kinds of abrasives which may usefully be referred to and their uses mentioned—

- (1) *Precious stones*, with diamonds at the head, would take the first place. They are practically all of a crystalline nature, and intensely hard. Rubies, emeralds, and sapphires are crystalline forms of pure corundum, whilst emery is an impure form.
- (2) *Sandstones* are used for whetstones, grindstones, and the grains of sand have a keen abrasive action, but the general use is in connection with building.
- (3) *Millstones*, of similar stone but coarser grained, is used as the name denotes for milling. The old homestead contained a hollow slab of millstone and, with a pestle of the same material, the corn was crushed. Later, large wheels were used in the flour mills.
- (4) *Pumice*, a volcanic product, is used entirely for abrasion.
- (5) *Quartz* or *felspar* is used for abrasion on wood and, in very fine powder or dust mounted on paper, is used for polishing hats.
- (6) *Kieselguhr* and *Tripoli* are soft abrasives and are used in the making of metal polishes and jewellers' polishes. These two are found in large quantities and are the fossilised remains of minute shell-fish.
- (7) *Corundum* is a pure form of emery and occurs in large quantities in Canada, where it is largely used for making grinding wheels.

And now as to *Emery*—probably the best known of all abrasives. It is found in the East—Turkey and Greece—where it occurs in large masses, and is composed of alumina oxide, mixed with a small percentage of iron and magnetite. Although used extensively, its place is being taken by artificial abrasives for many

purposes. Artificial abrasives are largely a product of the electric furnace and the best known are those produced by the Carborundum Co. and the Norton Grinding Co.

A comparison between emery and carborundums may be interesting, each being useful in their own sphere. Both stones have to be crushed and sieved into their own various grit numbers, the grits running from coarse No. 8 to 220 fine, but the carborundum never loses its crystalline formation and the grains are probably the hardest abrasive used in industry, the points or edges doing the cutting.

Emery, a natural stone, bluish-grey in colour when powdered, shows each grain to be filled with tiny cells, and it is the edge of the cells which do the cutting. Quite a different action from carborundum. One works best against a hard solid surface, like a C.I. cylinder, and the other will grind a springy substance like card-wire. It is imported into this country in lumps varying from a few pounds to two hundredweights. These pass through large crushing machines and sieves until the stone is reduced to pieces of about a quarter-inch size. Passage through steel rollers splits the stones. Further pulverising or grinding would produce flat or round grains, but splitting gives an angular grain. These in their turn have to be sieved. All the different sizes are separated, ranging from grit which will pass through a mesh with eight holes to the inch to material passing sieves up to 200 holes per inch. The uses are almost without number, but they can be roughly divided as follows—

Coarse Grains—for card grinding, leather, and glove grinding, boot and shoe industry, cloth cleaning, and grinding discs for engineering.

Medium—in engineering for grinding and glazing of castings, emery cloths, emery tapes, emery wheels, etc.

Fine—domestic emery cloths, electro-plating trade, valve grinding, sueding leather, cloths, etc.

On the subject of grinding as applied in the textile industry, it may be stated that when carding was first introduced, some method of correcting the wear was necessary and the points of the wire had to be kept sharp. Various methods must have been tried, but the first of which we have a record was that of using, by hand, a piece of rough sandstone. This was quickly followed by pulverising the sand and fastening it on to a flat piece of wood—the first hand strickle. A wooden roller covered in the same way was quickly evolved, and emery began to be used as a grinding medium. At this point, two distinct methods of grinding commenced and both developed gradually. The grinding-roller principle was developed and the strickle also became a machine. We still have the remains of a strickle machine which was used for grinding doffer and cylinder at the same time. It contains two strickles, 50 inches wide, mounted on a frame to which a slight traverse was given. This was followed by the travelling strickle, which consists of two large sheets of coarse emery-cloth mounted on a frame and attached by steel rods to a shaft which is cut with a right-and-left thread, and carries the strickles to and fro across the cards. This type is still in general use in condenser spinning, being used principally for the ring doffer.

The next development was a steel plate covered with emery which, whilst traversing, revolved at a high speed with the flat side towards the wire, but its action was too drastic and it passed away to be replaced by the emery traverse grinder. I do not propose to go into the details of its structure. It is a precision tool and should be used as such. There is probably no better made machine in a mill, yet it is often worked for twenty years without being overhauled. All working parts are case-hardened. The band of the grinder is finished off by grinding, likewise the shafts and disc. In the early days of its use, the traverse was obtained by leaving a pulley at each end, one to drive the barrel and disc

and the other to regulate the traverse, but this method has been almost superseded by attaching a differential motion. Even this is constantly being improved, for as the grinding of flats on carding engines by traverse grinders has become recognised as essential, the early difficulties of covering a flat with the grinder before it moved forward has been overcome. The latest invention is a silent roller-bearing motion which, with the disc revolving at 500 revs. per minute, will allow it to traverse across eight times, thus easily catching the whole of a flat.

To go back to the rollers. Many types were produced—extremely light tin ones; sheet-metal rollers with a steel shaft through; rollers with a coat of rubber under the emery, to give a cushion effect when grinding; circular steel files were tried at great expense; and cast-iron rollers. Some of the rollers had large diamond-shaped spaces around the roller. These spaces enabled a current of air to play upon the wire, whilst the small fibres of cotton which got rubbed up into a ball and might ignite could escape through them. It is to be remembered that the wire was mild, and grinding would be a great deal heavier than to-day. Finally, the makers of steel tubes were able to make them sufficiently large in diameter to enable them to be used for grinding rollers, and that is the type used to-day—a seamless steel tube built up with the same care and precision as the traverse grinder.

Now came the application of emery. As mentioned earlier, the grains must be angular and there are three grades in general use—coarse, medium, and fine. Glue has generally been used as an adhesive to hold the emery on to the metal, but with the introduction of synthetic resins, another and far better adhesive has come into use. I allude to Bakelite. We applied this method some years ago with great success. We find that not only do the grains of emery stand up better, but they grind quicker, last longer, are not affected by dampness, and, if necessary, can be washed.

The use of Bakelite has enabled us to develop other lines in cloth finishing. For instance, sand or take-up rollers on looms are now often covered with fine abrasive. We go as fine as 200's for this purpose and the abrasives are practically part of the metal and cannot come off. The points are extremely sharp, but being so small have a tremendous drag without penetrating the fabrics.

Perhaps the greatest developments have been in raising and sueding of cloths. Many cloths in both cotton and wool are now finished on Bakelite-emery rollers, shirtings and pyjamas, polishing cloths, face-cloths of all descriptions, velours, felts, light drills requiring a soft finish, cotton khaki drills, and even blankets are being worked up on them, whilst one energetic cloth finisher is actually putting a large variety of stripes into cloths suitable for upholstery and suitings. One of the principal features of these rollers is that they can be used wet or dry, and for many processes this has proved a great advantage. Another point is that the Bakelite will stand heat up to 350° F. without breaking down, whereas glue quickly gives way under frictional heat.

The contributor of the paper exhibited a number of specimens of fabrics which had been processed by the abrasive method, and brief discussion followed.

A question was asked as to whether the finishes secured in the case of stripe effects would withstand laundering, and Mr. Wareing replied that he could not give definite information on this point. Certain specimens in his possession, however, had shown no change after laundering.

London Section

*Meeting at the Barrett Street Trade School, London, on Wednesday,
11th January 1933; Mr. T. C. Petrie presiding.*

THE RELATIONSHIP BETWEEN THE TEXTILE AND LAUNDRY INDUSTRIES

This meeting was addressed by Dr. R. E. V. Hampson, Director of the British Launderers' Research Association, on the above subject. Introducing Dr. Hampson, the Chairman emphasised the importance of co-operation, in dealing with their many problems, between the manufacturer, the distributor, and the launderer.

Dr. Hampson stated that the common ground of relationship between the textile and the laundry industries was their mutual service to the public, and that therefore the more clearly each was able to appreciate the view point of the other, the better would such service become. The point of view forced upon the lecturer was the result of the examination of complaints. Study of some hundreds of complaints per annum gave an indication of how they arose and how they might be avoided. It was his intention, said the lecturer, not to deal with complaints of which the causes were definitely attributable to the laundry processing, since his audience would be more interested in the other large group of complaints of which the causes were to be found in some pre-laundering textile process. In the opinion of the lecturer, most cases of what were described as manufacturing defects were in reality questions as to the suitability of the fabrics concerned for the purpose to which they were applied. He gave particulars of several instances coming into this category, such as bath mats, chair covers, "unshrinkable" fabrics, terry towelling, etc. Some agreement was needed as to what might be expected in use and in laundering, and statements issued with the goods giving the public information on these points.

Dr. Hampson next made a comparison between a finishing process and the typical laundry process indicating wherein the real differences lie which can be summarised as—the finishing of textiles is concerned with goods of known characteristics, whereas the handling of goods in the laundry is a problem in which characteristics are largely unknown. Laundering must primarily secure classification so as to approximate to the position of dealing with goods of known characteristics. The lecturer pointed out, however, that classification in the laundry was always limited and certain distinctions could not be made with the time and methods available. But as sorting was very important he urged that clear marking of articles was one direction in which practical co-operation could proceed.

Another direction in which co-operation could move, said Dr. Hampson, was that of tests for "launderability." These tests were carried out by the Launderers' Research Association and an indication as to the most suitable laundry process for any fabrics so tested could be incorporated in the woven marks on the garments. Certain goods could not be considered "launderable" and to know this would surely remove a cause of complaint and disappointment. He wished to see this method of co-operation widely extended and if so was firmly convinced that it would result in the elimination of discussions between the launderer and the manufacturer which usually led nowhere and often alienated the goodwill of the public.

The lecture was followed by a good discussion, in which a number of members present took part. The chairman expressed the view that on the final results the launderer, distributor, and manufacturer stood or fell together.

It was urged by one speaker that research should be accompanied by advertising so as to educate the general public as to the properties and uses of goods supplied.

The fullest co-operation possible on the part of testing houses and research associations was urged by another speaker, who submitted that, as complaints were being dealt with by the organisations already, their co-operation would be most beneficial.

A member urged that agreement should be reached by all concerned as to the precise meaning of terms used. In his opinion the word "unshrinkable" should only be applied to wool which had been treated with chlorine.

Another point raised was in connection with cost. It was suggested that if anything was done to fabrics to render them "unshrinkable" or to impart any other property, or to indicate their limitations, that would enhance the cost. Recognition must be given to the fact that buyers would not give more than a fixed price for such and such goods, and that the customer could not be expected to discriminate between goods offered at different prices but stated to possess different properties.

The lecturer dealt exhaustively with all the points raised in the discussion, and a vote of thanks to him ended a very valuable meeting.

Irish Section

ELECTRICITY AND ITS APPLICATION IN TEXTILE WORKS

The second meeting of the session was held in the Municipal College of Technology, Belfast, on Thursday, 26th January, 1933, when a paper on "Electricity and its Application in Textile Works" was contributed by Mr. R. H. Friend, A.M.I.E.E.

The chair was occupied by Mr. F. H. Whysall, M.I.E.E., Chief Engineer and Manager of the Belfast Corporation Electricity Department, and there was a large attendance of members and friends. Introducing Mr. Friend, Mr. Whysall said he was deeply interested in the subject of the lecture and for some time had been doing his best to persuade those in the textile industry to adopt electricity in their works as far as possible.

Mr. Friend dealt comprehensively with the whole system of driving textile machinery and pointed out the great advantages to be obtained by individual electric drives over group driving. The lecturer also explained how the special requirements of individual machines are met by motors specially designed for these applications. On the subject of lighting, Mr. Friend discussed the requirements of the various processes, showing the methods in use for obtaining uniform shadowless lighting of each room and the local lighting of individual machines.

The paper was much appreciated by a large audience and a very interesting discussion followed. On the motion of Mr. J. Earls, B.A. (Principal of the College), seconded by Prof. Bradbury, a hearty vote of thanks was passed to the lecturer.

Yorkshire Section

MEETING AT HALIFAX

In view of the successful character of a meeting held at the Bradford Municipal Technical College in February last, when students and others were addressed on the subject of the Diplomas of the Institute, a similar fixture was promoted and held at the Technical College, Halifax, on the evening of Monday, 27th March. The Principal of the Halifax College took an active interest in the arrangements for the gathering and there was an excellent attendance. The Chairman of the Section (Mr. J. Dumville) presided and the President of the Institute (George Garnett, Esq., J.P.) spoke on the value of the Institute qualifications to the textile industry. Dr. J. B. Speakman, of Leeds, contributed a most useful explanatory statement in regard to the Institute's examination, dealing more particularly with the requirements and the objects of Part II of the examination

(General Textile Technology). The General Secretary (Mr. Athey) dealt with the regulations governing awards and the procedure in connection with applications for the Associateship. Questions were invited and the response clearly demonstrated marked interest in many aspects of the whole subject.

Midlands Section

VISIT TO MESSRS. I. & R. MORLEY'S SILK-HOSE FACTORY AT SUTTON-IN-ASHFIELD

On 14th December 1932 about twenty-five members of the Midlands Section visited the silk hose factory of Messrs. I. & R. Morley at Sutton-in-Ashfield. This is one of the firm's five factories, each of which specialises in the manufacture of some type of knitted goods. Transport, kindly provided by the firm, awaited the members at Victoria Station, Nottingham, and the party proceeded in charge of one of the partners, Mr. H. F. Lilburn, to Sutton-in-Ashfield. At this factory the firm receive raw silk from Japan and elsewhere, and proceed to follow out all the manufacturing processes up to the dyeing, which is carried out by the firm at another factory. The silk is first prepared and thrown, and whilst still in the gum knitted into silk hose.

Great interest was taken in the visit and the various processes were fully explained by the local manager. Briefly these are as follows—After the threads have been prepared and thrown they are wound, chiefly on cones, and taken to the legging frames, which make up to 24 legs at once. The legs are taken to the footing frame—and it is interesting to state that all legs are footed on the English foot principle—and afterwards linked and seamed. The machinery proved to be of a very recent type, and frames capable of producing all-over or pattern lace with full jacquard were seen in operation.

Tea, also provided by the firm, was partaken and a vote of thanks, proposed by Mr. Thomas Morley, Chairman of the Midlands Section, was responded to by the local manager in the absence of Mr. H. F. Lilburn, who had been called away. The members greatly appreciated the trouble Messrs. I. & R. Morley took to explain the operation of these fine gauge frames and were impressed by the excellence of the firm's productions.

VISIT TO MESSRS. A. W. SWANN & CO. LTD. FACTORIES AT SAWDAY STREET AND BRAZIL STREET, LEICESTER

On 16th March the members of the Midlands Section visited the works of Messrs. A. W. Swann & Co. Ltd., Brazil Street, Leicester. There was a poor attendance, only twelve members being present. The feature of these works is the manner in which they are organised to carry out the mass production of a standard garment, viz. ladies' knickers.

The members were shown round the works by one of the Directors, Mr. Arch. W. Swann, and saw the whole of the operations, viz. winding, knitting, cutting, making-up, and finishing. Mr. Swann explained how the goods were got through at speed, and stated that it was possible to complete a thousand dozen order in a single day. Unfortunately, he continued, the present tendency is to receive smaller orders in a greater variety, and this seriously interfered with the team system.

The members expressed their appreciation of Mr. Swann's kindness in explaining the processes so much in detail, and were surprised at the manner in which variety in a single article was developing. Mr. Swann replied and stated that whereas a few years ago only twenty varieties of knickers were made by the firm, at the present time over 150 kinds were produced. Knickers were now being made from plain, rib, locknit, tuck, fleecy, interlock, and other fabrics, in innumerable sizes, styles, and shades, and the company had recently installed a large plant of interlock machines.

NOTES AND NOTICES

Annual General Meeting

Nomination forms in connection with the current year's election of ten members of the Council of the Institute were recently issued to members. As the number of nominations received exceeds the number of vacancies created, a postal ballot will be necessary. The last day for receipt of nominations was the 17th April. It is intended to issue ballot papers on the 27th April, together with notices convening the Annual General Meeting, and copies of the annual report of Council and audited accounts and balance sheet. As previously announced, the Annual General Meeting is to take place on Wednesday, 17th May—to be preceded by a meeting of the Finance and General Purposes Committee at 12 noon and by a meeting of Council at 2 p.m.

Institute Examination

In connection with applications for the Associateship of the Institute, the current year's examination has been fixed to take place on the 14th June (Part I, Auxiliary Subjects), and 21st June (Part II, General Textile Technology). The examination is only available to members of the Institute whose applications for the Associateship have been approved for candidature. Part I (Auxiliary Subjects) becomes operative this year for the first time, and it is likely that there will be few candidates. This part of the examination will be conducted at Manchester. A large number of candidates are due to take Part II (General Textile Technology). A report was presented at last meeting of the Selection Committee (5th April) indicating the geographical distribution of the candidates. Up to the date of that meeting, there were 17 candidates for Part II, with a possibility of 8 additional acceptances. It was agreed that arrangements be effected for the simultaneous conduct of this part of the examination at Manchester, Leicester, Glasgow, and Belfast; also at Bombay (India) and Calcutta (India) if candidature matured in the case of certain applicants in India who had been referred to examination.

Annual Conference—at Harrogate from 7th June

The early response of members of the Institute to the preliminary invitation in respect of our forthcoming Conference at Harrogate has been of a most satisfactory character. The indications are that an excellent attendance will be recorded. The event will take place in the latter part of Whit-week—7th to 9th or 10th June. It is now possible to state definitely that the proceedings will commence on the evening of Wednesday, 7th June, by a Civic Reception, followed by a musical programme, dancing, and refreshments, at the Harrogate Winter Gardens. The Conference proceedings will open at 10 a.m. on the Thursday morning, and in the afternoon there will be an excursion to York. The N.E.R. Company offer to convey the party by special train, and Messrs. Rowntree & Co. Ltd., have kindly agreed to provide for an inspection of their works. An outline of programme has been issued to members, together with a list of the papers to be presented on various problems in connection with the finishing of textile fabrics. In regard to railway travel to and from Harrogate, it will not be necessary to provide special vouchers for securing return tickets at reduced fares, as commencing 1st May, the summer tickets scheme of the railway companies, which provides for the issue of return tickets (available for return any train any day within one calendar month) at single fare and a third will apply to Harrogate. The Secretary of the Institute hopes to be able to issue Attendance Forms and further particulars, including hotel accommodation and charges, not later than the first week in May.

Institute Scholarship Holder

At the March meeting of the Council of the Institute, a report was presented in regard to the present occupation of the first holder of the Scholarship of the Institute awarded under the terms of the scheme inaugurated as a result of a contribution to the Institute Foundation Fund by the Cotton Reconstruction Board and the Trustees of the Cotton Trade War Memorial Fund. After two years of special training at the Manchester College of Technology, during which period he qualified for the Associateship of the Textile Institute and successfully passed the Examination in General Textile Technology, the first scholarship-holder, Mr. Alan Ratcliffe, proceeded on the Continent for the widening of his experience in both mill and commercial practice. Following about six months of commercial experience in the Chemnitz district of Germany, Mr. Ratcliffe is now concluding his year abroad at textile works in Denmark. The Council calls attention to the fact that the services of Mr. Ratcliffe will shortly be available for employment in industry, and it is hoped that suitable appointment may be secured in the cotton industry of this country. Replies to the following announcement may be directed to the General Secretary of the Institute—

Textile Institute Scholarship holder, seven years of practical mill experience, two years of University training in Textiles and Business Administration, followed by one year of industrial experience abroad, will be free on 14th of July next, and seeks administrative position of responsibility.

The Institute Library

In connection with the lending facilities associated with the Library of the Institute at Headquarters, satisfaction was expressed in regard to the record of service to members at a recent meeting of the Library Committee of which Mr. J. Read, of Salford, is Chairman. Loans of books and other literature for the period 30th September last year to 31st March of this year reached 303 (1 catalogue, 5 pamphlets, 71 books, and 226 periodicals). The existing printed catalogue of books, etc. is to be retained, but a complete typewritten and duplicated supplement is to be prepared for issue with the printed catalogue. A new cabinet has been secured for the accommodation of current periodicals. The cabinet is in harmony with the unit bookcases of the Library, and it has been constructed so as to provide considerable additional storage accommodation.

Federation of Textile Societies

By invitation of the Oldham Technical Association and Old Students' Union, the Annual Meeting and Conference of the Federation of Textile Societies and Kindred Organisations will take place at Oldham on Saturday, 6th May. Notices of the event have been issued to all the Societies in membership of the Federation, and each organisation will appoint delegates for attendance. The programme shows that the delegates will meet at 10 a.m. at the Municipal Technical College and parties will proceed (a) to the Works of Messrs. Platt Bros. & Co. Ltd. and (b) to the ring-spinning mill of the Moston Mill Co. Ltd. After inspection, there will be a reassembly at 12.15 p.m. at the College, when the textile department will be open for inspection. At 1 p.m. luncheon will be served at the Union Club, at which function the Mayor of Oldham (Ald. E. Bardsley, J.P.) has kindly engaged to attend and welcome the delegates to Oldham. The Annual Meeting and Conference of the Federation will subsequently take place at the College, and a paper will be contributed by Mr. G. H. Thompson, F.T.I., on "Oldham: Its Progress and Industries." Mr. W. Munn Rankin, M.Sc., of Burnley, is the retiring President of the Federation, and the President-elect is Mr. E. M. Roberts, of the Bradford Textile Society, who has occupied a leading figure in the textile-society movement for many years. The invitation to hold the Federation annual fixture at Oldham arises owing to the fact that the Oldham Technical Association has this year attained its majority.

Analysis of Warp Knitted Fabric

A request has recently been received by the Information Bureau of the Institute for a means of dissecting warp knitted fabric for analysis. The inquirer says—"My difficulty at the moment is in separating from warp knitted material in garment form the original warp threads so that these can be examined individually." A communication from a member who kindly agreed to reply, states that "there is no royal road to separate the warp. Your inquirer must assume he has a piece of string which has been tied into a number of knots, each of which required untying—I am sorry I am unable to give an easy, infallible method—there isn't one." Acknowledging this reply, our inquirer pointed out that for his purpose it was essential that the whole of the warp threads be tested one after the other, the alternative of testing the cloth in strip form not being satisfactory. Under the circumstances, it appears that the matter is one of more than passing interest and any communication of help in the direction of furnishing a reliable method of analysis would be appreciated.

Textile Institute Diplomas

Election to Associateship has been completed as follows since the appearance of the previous list (March issue of this *Journal*)—

ASSOCIATESHIP

HYAM, Aaron E. (Bombay, India).

Institute Membership

At the April meeting of the Council, the following were elected to membership of the Institute: *Ordinary*—J. B. Butler, Leigh & Butler, 74 Corporation Street, Manchester (Textile Machinery Exporter); E. L. Freeman, 92 West Warren Avenue, Detroit, Michigan, U.S.A. (Manufacturer of Surgical Elastic Bandages, etc.), *Junior*—S. Appleyard, 11 New Park Street, Morley, near Leeds (Assistant Designer); W. L. Wright, "Highgate House," Clayton Heights, Bradford (Organising Dept., S. Selka). *Life Membership*—M. M. Shah, The Gujarat Spinning Mill, Railwaypura Post, Ahmedabad, India (Weaving Master. Elected to Ordinary Membership in 1927).

REVIEWS

The General Tariff of the United Kingdom (Law and Regulations). By A. S. Harvey. 1933. Published by Sir Isaac Pitman & Sons Ltd., London. (177 pp. and Index, 5s. net).

He would be a harsh critic indeed who would not accord a very definite welcome to this book, both for the courage and care which its production must have involved and for the very valuable information which it gives. Doubtless those in the community who realise most clearly the implications of our adoption of a general tariff are those whose daily business is directly affected, and Mr. Harvey's book will provide the answer to many of their queries. It deals essentially with points of detailed practice rather than with the economics of trade regulation. But here, too, the academic student is provided with much realistic background which will be a great asset in his effort to bridge the gulf between theory and realism. No better example surely could be given than the doubt which recurs in one's mind as to the basis on which *ad valorem* duties are in fact based, and knowing that it is possible to work out the practical counterpart of the theoretical controversies which centre round the use of anti-dumping duties.

The book suffers two obvious defects. First, events have moved so quickly that a true picture of the present position can only be derived by consulting new enactments and regulations which are now operative. This difficulty should be overcome to some extent when the book goes to its next edition. Secondly, while the information given is as complete as the size of the book would permit, the business man will need to seek the answer to many points of detail elsewhere.

To say that the book is not easily readable is no valid criticism of a work of reference, but something could have been done to present the outstanding features of the system in readable style. Finally one must sympathise again with anyone who undertakes the task of presentation of so highly complicated a position, and the question naturally arises as to whether it could not with great advantage have been avoided to some extent. To take an example at random (p. 87), the Finance Act 1925 provides *inter alia* that duty stipulated for imported negative cinematograph films, whether developed or undeveloped, shall be subject to abatement if the following circumstances are proved to the satisfaction of the Commissioners—

- (a) that the production of the film was organised by persons whose chief, or only place of business was in the United Kingdom, and
- (b) that the producer of the film and all the principal actors and artists employed for the production thereof, except five, or if the total number of the principal actors and artists is less than 20, not less than three-quarters of the principal actors and artists, were British subjects and domiciled in the United Kingdom.

What constitutes a "chief place of business," a principal actor or artist? Beyond the fact that the camera man is technically regarded as an artist we are left in doubt.

Whether we like it or not, it is incumbent on us to attempt a critical study of tariff technique and to that end Mr. Harvey's book is a welcome and valuable aid.

S.G.R.

Verfahren, Normen und Typen für die Prüfung der Echtheitseigenschaften von Färbungen auf Baumwolle, Wolle, Seide, Viskosekunstseide und Acetatekunstseide, 6th Edition, 1932. By the Echtheitskommission der Fachgruppe für Chemie der Farben- und Textilindustrie im Verein Deutscher Chemiker. Published by Verlag Chemie, G.m.b.H., Berlin (59 pp., 3.60 R.M.).

The first report of the German "Fastness Committee" was published in 1914. It contained approved methods for testing the fastness properties of dyed cotton and wool, recommended a scheme for grading dyed materials according to fastness, and illustrated the system of grading with certain "type" dyeings. Later editions were chiefly concerned with extending the methods to other textiles (silk, and the rayons), and to other fastness properties. Considerable changes have been made in the type dyeings, but the grading scheme and the methods of testing remain, on the whole, much the same as those recommended in 1914.

The present edition differs from its predecessors chiefly in a unification of the type dyeings used to classify the light fastness of dyed materials. According to the earlier recommendations the fastness of dyed cotton to light was judged by comparing it with eight standard dyeings on cotton, graded so as to form a series of increasing light fastness in the order 1 to 8; the fastness of dyed wool was judged by comparison with eight other standard dyeings on wool, the fastness of dyed viscose rayon by means of yet other dyeings on viscose. According to the present recommendations all dyeings, on whatever material, and of whatever shade or depth, are to be compared with eight standard blue dyeings on wool. Thus, the highest grade of light fastness—Class 8—is now uniquely typified by Indigosol Blue AGG on wool, whilst in earlier reports it was typified by Indanthren Blue GC on cotton, Indigo on wool, and Indanthren Brilliant Violet 2R on silk. The type for Class 7 is now Indigosol AZG on wool for all dyeings. In a formal sense, the change evidently represents a simplification, but since the Committee does not publish the experimental evidence forming the basis of its recommendations, the effect of the change on the grading of dyeings cannot be predicted.

The progress made during the first 20 years following the first report of this Committee is disappointing, and the time is much overdue for a complete and argued revision of the recommendations. The changes in the testing methods bear little evidence of reflecting a better understanding of the physical and chemical conditions that determine the fastness of dyes. The methods recommended for testing the fastness of dyeings to hypochlorite solutions are, for example, ten years behind present day knowledge of the chemistry of hypochlorite oxidation processes as it affects textile practice.

Much could be done to improve the report even on purely formal lines, since a system of repeated re-editing consisting chiefly in the addition of fresh sections

has resulted in a very patchwork production. Thus, the concentration of the liquor used to test the fastness to soda boiling is given as 10 g. of soda ash per litre, and that for a test of fastness to kiering as "4 c.c. of 40° Bé caustic soda per litre." In 1928 the kiering liquor was described as "10% of 40° Bé caustic soda on the weight of the material." A uniform and rational system for the expression of concentrations is expected from a scientific committee.

The nomenclature of the different kinds of fastness is often irrational. The test for kiering fastness (Bäuchheit) of dyed cotton is made to include a bleaching treatment with a hypochlorite solution. The test for "Peroxide Fastness" of dyed cotton, in one of its variations, also includes a hypochlorite treatment. Of all the textile fibres, only dyed cotton possesses a "Peroxide Fastness," but dyed viscose rayon, unlike cotton, has a "Bleaching Fastness," which is in fact the fastness to a defined peroxide treatment. Nothing but confusion can result from a system of testing which attempts to copy local industrial language and practice.

It is interesting to notice that the test for the so-called "Bleaching Fastness" (peroxide) of dyed viscose rayon includes a specification of the pH of the liquor. How fitting it seems that the bleaching of such a modern textile as rayon, with such a modern bleaching agent as peroxide, should be controlled by such a modern idea as pH .

Although it is difficult to give unqualified approval to the recommendations of the German Fastness Committee, its work deserves sympathetic and appreciative recognition. A completely satisfactory system for testing and grading the fastness properties of dyed materials is evidently impossible without a full understanding of all the physical and chemical conditions that determine dye-fastness in its numerous aspects. The fact that we do not possess this fundamental knowledge, nor are likely to possess it for many years to come, is not an adequate reason for refraining from devising as satisfactory a scheme as present knowledge permits. The urgent need of the dyeing industry for some grading method was at least partially satisfied in Germany, thanks to the work of the Fastness Committee, and it is no belittlement of this achievement to suggest that the time has come for a comprehensive revision of the report.

The recommendations of the German Committee do not receive the official approval of any representative body in this country. We have no official system for describing the fastness of dyeings, nor is this the worst that can be said. Grading systems are in use which are not referred to any published system of testing. Thus in the British dyestuff-makers' colour cards a method of classification is employed containing eight grades of light fastness, and five of fastness to washing, "chlorine," etc. Formally, this is the German system, but the methods of testing that form the basis of the classification is a matter for speculation. Whatever it may be, it results, for example, in the same dye on cotton being classed as much faster to soda boiling in England than in Germany.

The issue of a comprehensive testing and grading system by an authoritative body in this country commanding the confidence of the industry is long overdue. The success of such a system will greatly depend, however, upon securing the co-operation and approval of the widest circle of interests, technical and scientific, in this country and abroad. D.C.

Cotton. G. Kränzlin and A. Marcus. Wohltmann-Bucher 1 Bd. 9. Published by Walter Bangert, Berlin-Charlottenburg (169 pp. 1931. 6 Rm.).

In this small handbook, which is the ninth of a series of Monographs on Tropical Agriculture, the authors have brought together general information which should be indispensable to all agriculturists or research workers concerned with the cultivation or investigation of the cotton plant. Starting with a general account of the plant and the morphology of its vegetative and reproductive organs, the authors pass on to a brief discussion of the species and varieties, limiting the reference to those which have any agronomic importance. The greater part of the book is taken up by general questions of cultivation, but one chapter is devoted to breeding and seed production. The various characters, such as lint percentage, index, and length, etc., which occupy the attention of the breeder are defined and the methods of breeding briefly reviewed. Selection methods are treated rather more fully for the sake of cultivators who are earnestly recommended to practice selection. A special chapter is devoted to the choice of

varieties and an indication is given of the growth conditions suited to each type. Further reference is made to the question in the chapter on pests and diseases.

P.G.

Sisal and other Agave Fibres. F. Tobler. Wohltmann-Bucher I Bd. 10. Published by Walter Bangert, Berlin-Charlottenburg (104 pp. 1931. 5 Rm.).

The tenth number of the series of Monographs on Tropical Agriculture of which "Cotton" was the ninth. The material embraces not only the Indian and African Agaves, but also those of Central and South America. The book is arranged on lines similar to those described for "Cotton." In the section on breeding, the author discusses the existence of different races in the vegetatively propagated material, and the desirability of examining these and selecting the ones most suited to any particular vicinity. A study of the Agaves in the regions of their ancient cultivation and possibly origin, *e.g.* Yucatan, revealed rather marked differences between forms, closely associated with differences in ecological conditions. Great significance is attached to this from the point of view of introduction and breeding. A number of useful indications is given as to the characters on which breeding should be based. Amongst these, of rather special interest is the length of life of the plant, differences of as much as 15 years in this respect having been observed in African sisals. The production of fertile flowers and fruits by lopping the poles is mentioned. A further obstacle in cross breeding is the unusual length of time which elapses before flowering. It is pointed out that the use of early maturing types is a disadvantage from the point of view of fibre production, although a regular system of replanting of short-lived plants would have the recommendation that the fibres produced from such plants would be of a higher quality.

P.G.

PUBLICATIONS RECEIVED AND ADDED TO THE INSTITUTE LIBRARY

An Industrial Survey of the Lancashire Area (excluding Merseyside), made for the Board of Trade by the University of Manchester. (380 pages.)

One of a series of industrial surveys prepared by a University at the invitation of the Board of Trade. It is significant that such invitations should have been extended and the response, in this case at any rate, more than justifies the confidence firmly held by many that for such tasks the modern provincial University is adequately equipped. It is not only impossible to summarise the contents of this Survey, but undesirable, as to do so would perhaps cause some potential student of the volume to fail to study it himself—and every Lancashire man, at least, ought to do that.

The Australian Market. Published by P. S. King & Son Ltd., Westminster.

A memorandum prepared in Australia for the guidance of British manufacturers by the Australian Association of British Manufacturers. There is a foreword by Sir Arthur Balfour, Chairman of the British Council of this Association.

Memorandum on the Industrial Diseases of Silicosis and Asbestosis. Printed and published by H.M.S.O. (Price, 3d. net.)

This memorandum deals mainly with Silicosis, but has a note on Asbestosis and particulars of the 1931 Compensation Scheme, No. 344.

Oilseeds and Vegetable Oils. Compiled by the Empire Marketing Board. Published by H.M.S.O., London. (Price, 6d. net.)

A summary of figures of production and trade relating to copra, groundnuts, cottonseed, linseed, olive oil, soya beans, sesame seed, rapeseed, palm kernels and oil, and whale oil.

Annual Report of the Chief Inspector of Factories and Workshops for the year 1931.

Published by H.M.S.O., London. (Price, 2s. 6d. net.)

An annual report of more than usual interest, as it reviews progress over the last ten years in the work of this important Government department.

An Experimental Study of Certain Forms of Manual Dexterity. By J. N. Langdon.

Issued by the Industrial Health Research Board. Published by H.M.S.O., London, 1932. (Price, 1s. net.)

A record of certain specified tests of manual dexterity and the industrial application of such tests; with particulars of analogous operations actually occurring in industry.

Jute: the International Annual of the Industry. Published by the British-Continental Press Ltd. (Price, 10s. net.)

A publication covering an important but little-known field. Deals with jute research; speciality tissues; jute in the cable industry; the jute yarn count; and modern jute machinery.

Rapid Testing by Fluorescence. A booklet issued by the British Hanovia Quartz Lamp Co.

A brief outline of the practical uses of the analytic quartz lamp.

Empire Fibres for Marine Cordage. Reprint from the *Bulletin of the Imperial Institute*. Published by John Murray, London, W.

This report gives an account of the service trials which have been carried out by the Admiralty to ascertain whether ropes composed of East African Sisal can be safely employed for the marine purposes to which Manila ropes have been applied.

Incorporated Accountants' Year Book, 1933. Published by the Society of Incorporated Accountants and Auditors, London.

Embodies a list of members and the regulations of the Society.

The Textile Recorder Year Book, 1933. Published by John Heywood Ltd., Manchester. Price 7s. 6d. net.

This is a useful work of reference despite the misnomer embodied in its title. The really new matter, applicable to the year-book aspect of the volume, might with advantage come at the beginning of the book.

Report of the Water Pollution Research Board for the Year ended 30/6/32. Published by H.M. Stationery Office, London and Manchester. Price 1s. net.

A report of interest to all users of water for industrial purposes. Deals with river pollution and methods for its prevention, mainly at the industrial sources of polluting discharges.

Department of Scientific and Industrial Research. Report for the Year 1931-32,

Published by H.M. Stationery Office, London and Manchester. Price 3s. net.

The Advisory Council of the Department says "no industry can afford in these times to neglect any opportunity for increasing its efficiency and, of all the means to this end, the pursuit of research, and the application of the results achieved are often the most far-reaching and fruitful." The report gives a full and valuable account of the year's work in all the various aspects of industrial research, and in so doing affords ample evidence of the truth of its dictum quoted above.

GENERAL ITEM

History of the Northrop Loom

Doctor Cartwright refers in some of his writings, about 1786, to the need for a warp stop motion on the loom. Other inventors were at work on devices for replenishing the weft as early as 1840. In the year 1888 the firm of Messrs. Geo. Draper & Sons, in Massachusetts, who already manufactured spinning machinery, began research into weaving machinery also in order to improve the process of manufacturing cloth. They felt that it was wise to spend effort in the line that promised the greatest chances for saving. The weaving shed, with its highly paid labour receiving about one half of the labour expenditure for the usual mill, was evidently the proper field for this investigation, especially as in no other department was there so much physical labour expended per pound of product.

It was quickly decided that an automatic device for changing the shuttle would be the greatest means of reducing the weavers' labour, and they appropriated a certain definite sum and set an inventor at work on the problem. This man's name was James H. Northrop. At first he was at work on a shuttle-changing device, and in the spring of 1889 he was joined by a man named Jackson from Yorkshire, in England, who had already worked out an idea for changing the shuttle in the loom automatically. Within a few months James Northrop decided that the system of changing the shuttle was not ideal from the mechanical point of view, though Jackson had by this time made a loom which was running in the factory of Messrs. Geo. Draper. Northrop therefore

left the Draper firm and began working on his idea of changing the *bobbin* in the shuttle. He carried out his experiments in a hen house on a farm, and in less than six months he had produced a loom running at 150 picks per minute with an automatic cop-changing device. Being destitute he applied to the Draper firm for assistance, and they took him back into their factory to work once more with Jackson. He would not disclose his idea however, and shortly afterwards left them once more. Shortly after this Jackson also left the Draper firm, as little progress was made with his idea of changing the shuttle.

It was then that the group of inventors which were to make loom history began to work on various ideas, which were eventually grouped together on one loom, which is now known as the Northrop. This group consisted of Ira Draper, who invented the first self-acting loom temple; General Wm. F. Draper, and Geo. Otis Draper; Charles F. Roper, who invented the automatic let-off motion; Edward S. Stimpson, who invented the self-threading shuttle; and finally Jas. H. Northrop, who invented the magazine for containing a supply of weft bobbins, and mechanism for transferring them automatically into the shuttle *without stopping the loom*. General Draper soon got hold of James Northrop once more, and immediately recognising the value of his ideas, brought him into the firm on a permanent basis. This man was born at Keighley, in Yorkshire, England, on 8th May 1857. He was employed as a foreman in a factory and went to America in May 1881. On 5th March 1889, Mr. Draper drove to his farm and saw Northrop's first loom, which was set up in his hen house. The firm ordered another loom for experiments, and after its arrival Mr. Northrop was started on the 8th April to work out his scheme. By the 20th May he made the first practical working model, and by the 5th July the first loom was made in the shops. By the 24th October the first Northrop looms were running in a weaving shed. This was at the Seaconnet Mill in Fall River. By April 1890 there were 100 Northrop looms running in this mill with one operative minding 12 looms. This was the start of automatic weaving.

Meanwhile the Draper Corporation were developing the construction of the loom, apart from the magazine, and it was not long before the other automatic motions, namely; the let-off, warp stop motion, feeler motion, improved take-up motion and spring wind-up motion, allowing the cloth to be removed without stopping the loom, were all produced; and what may be called the first standard model of a fully automatic loom was produced in 1895.

By 1900 Messrs. Geo. Draper had sold 75,000 of these Northrop looms, and weavers were running up to 24 plain looms each. In 1901 they turned out 24,000 Northrop looms, and had applied the Northrop magazine to some thousands of their older ordinary looms. The same firm to-day, which is now known as the Draper Corporation, have a plant which can turn out as much as 600 looms per week, which is one for every five minutes of the ordinary working day.

In 1902 the British Northrop Looms Co., was founded to manufacture Northrop looms in England, under the Draper patents. In the autumn of the same year licenses were also granted to necessitous loom makers in France and Switzerland for the same purpose. To-day, nearly every textile machinery maker in Europe of repute in loom making makes the Northrop automatic loom. Very little change has taken place in the design of the automatic motions on the loom, and Northrop's original magazine is practically the same, which is a striking testimony to his ability and original idea. Improvements and greater accuracy in manufacture have of course had their effect, so that now in the U.S.A. a weaver minds up to 100 or more plain looms, in exceptional cases, whilst 48 to 60 looms per weaver is quite common. The greatest development and departure from the original Northrop loom has, however, been made in England, where the demands of the trade are more varied and particular. Northrop automatic looms are now made by the British Northrop Co. for all kinds of yarn, cotton, silk, artificial silk, linen, wool, worsted, flax, jute and hemp, etc., with one to four colours of weft. The latter is a check loom fitted with a magazine having electrical control, which was the invention of an Italian manufacturer—Ing. Felice Leumann, of Turin. These English Northrop looms are made from 50 cms. to 3 metres 50 wide, both light, medium, and heavy, and they can be fitted with all types of shedding motions, tappets, dobbies, or Jacquards, for weaving a very large variety of fancy cloths.

THE JOURNAL OF THE TEXTILE INSTITUTE

Vol. XXIV

MAY 1933

No. 5

PROCEEDINGS

TWENTY-THIRD ANNUAL GENERAL MEETING AT MANCHESTER

The Annual General Meeting of members was held at the Institute, 16 St. Mary's Parsonage, Manchester, at 3 o'clock on Wednesday, 17th May. The President, Mr. George Garnett, J.P., of Bradford, occupied the chair, and there was a good attendance.

In moving the annual report, Mr. F. Nasmith said that as Honorary Secretary, he was in close touch with the General Secretary, Mr. Athey, and the Editor, Mr. Robinson, and he could assure them they were doing all the work that it was possible to do with the funds at their disposal. The tremendous amount of work that was done yearly by the Textile Institute was having effect not only in the immediate area, but throughout the whole of the textile industries. It was only due to the shortage of funds that they were not extending very rapidly. He then referred to the outside activities of the Institute and gave a detailed list of organisations, committees, etc., upon which the Institute was represented. Members were rendering excellent service in this way, said Mr. Nasmith.

Referring to the Institute's own work, Mr. Nasmith said that two scholarships were in operation as a result of the fund provided by the Cotton Reconstruction Board and the Trustees of the Cotton Trade War Memorial Fund. The holder of the first, Alan Ratcliffe, was just about to conclude three years of special training. After taking a special course at Manchester College of Technology with marked distinction, he proceeded for a year of Continental experience—first in Germany (Chemnitz and district), and was now at Veile, in Denmark. His scholarship period expired and he will return to this country about the middle of July, and it is confidently expected that his services may be quickly absorbed in the cotton industry of Lancashire. The members of the Scholarships Committee were convinced that he would acquit himself admirably in any suitable post he may be called upon to occupy.

The second scholarship holder, William Graham, was just about to conclude his two years of special studies at the same College, and we had excellent reports of his progress. In July, he would commence a year of experience on the Continent and was to proceed, in the first instance, for six months of experience at the works of Messrs. Diederichs, at Ste. Colombe, in the Lyons district of France.

It was only by the general effort and by the expenditure of considerable time by many of the members of the Institute that they had been able to carry on all these activities. He thought they ought to pay Mr. Athey, the General Secretary, and Mr. Robinson, the Editor, a high compliment for the work they were doing.

Major W. Vernon seconded, and the report as printed below was adopted.

COUNCIL'S ANNUAL REPORT

A full programme of established activities is now in operation and, notwithstanding the need for extreme vigilance in regard to commitments in annual expenditure, the Council is pleased to be able to report that the maintenance of an enterprising policy has been accompanied by marked improvement in the financial position. In this connection, however, the fact that the annual income by way of interest from invested funds will be considerably decreased in the current year is not overlooked. The numerical record of membership shows little or no change as compared with the previous year. Nevertheless, the fluctuations during the year have proved somewhat remarkable and have reflected the prevailing uncertainty in regard to trade and industry. Withdrawals from membership have been exceptionally numerous; on the other hand, the additions to membership have far exceeded any previous record for a single year. The evidence for the early part of the current year is definitely towards abatement of withdrawals, whilst the monthly influx of new members is fully maintained. The Institute's services to its members have been developed in several directions. Last year's Annual Competitions included, for the first time, a section for knitted fabrics, whilst the prospectus for the present year contains a section for designs for printed fabrics. The Library equipment has been extended and the facilities for borrowing books have been improved with advantages to all concerned. The Employment Register and the Information Bureau are contributing substantially to the services. The problem of accommodation at the Institute premises is under serious consideration, and although the matter is not immediately urgent, it is felt that the question of extension of accommodation will need to be dealt with in the near future.

Balance Sheet and Accounts

The Annual Balance Sheet and Accounts (to 31st December 1932), which accompany this report, are of a satisfactory and encouraging description. The Revenue Account shows a reasonable surplus of income over expenditure, as compared with an augmented deficit in the previous year, due to exceptional items of a more or less non-recurring character—Coming-of-Age Celebrations, Income Tax, and Special Publications.

Annual Conference

Held in the latter part of Whit-week of last year, the Annual Conference was the occasion for the contribution of a series of papers on various aspects of the subject of testing of textiles. So successful was the experiment of dealing comprehensively with one general subject that a similar arrangement is to be pursued in regard to the Conference for the current year, which is to take place at Harrogate during Whit-week—from Wednesday to Saturday—when papers will deal generally with Problems of Finishing. The Annual Mather Lecture was delivered at Leamington by Sir Michael Sadler, K.C.S.I., Master of University College, Oxford, whose subject was "Liberal Education and Modern Business." The Council appreciated the ready response to their invitation by Sir Michael Sadler, and the event afforded a fitting opportunity for reawakening of the friendship which had existed between the Institute and the Lecturer during the period when he occupied the position of Vice-Chancellor of the University of Leeds. The Mayor of Leamington (Ald. Dr. R. F. Bury) warmly welcomed the Institute members and their friends, and the municipal authority provided excellent facilities and accommodation for the conduct of the proceedings. In appreciation and recognition of services to the textile industry, and in particular to the Institute, the Medal of the Institute was presented to Mr. W. Kershaw, F.T.I.

Later in the year, the Institute Medal was also presented to Mr. A. Abbott, C.B.E., in recognition and appreciation of his services to textile technical education. The presentation took place at a special luncheon meeting arranged by the Council at Manchester, and the event marked the retirement of Mr. Abbott from the position of Chief Inspector, Technological Branch, Board of Education.

Journal of the Textile Institute

The *Journal Account*, included among the other accounts of the Institute for 1932, indicates a very definite improvement over 1931, both in income and expenditure. In actual contents the issues for the year exceeded those for the preceding period by 34 pages

only, but whilst there were marked increases in the Advertisements, Proceedings, and Abstracts Sections, the Transactions Section showed a definite decrease. This was largely due to the time and manner in which contributions were received and dealt with, but as an offset it is to be noted that the first two issues of 1933 contained more than twice as many pages as in the corresponding period for the previous year.

The outstanding feature of *Journal* work for 1932 was the development of the abstracting schemes previously existing.

The Abstracts now appearing in the *Journal* are supplied by the Cotton, Launderers, Linen, Silk, and Wool Research Associations directly, and by arrangement with several abstracting organisations, such as the Imperial Bureaux of Plant and Animal Genetics. Arrangements are being made to abstract several Russian and Japanese periodicals, and when these are completed the abstracting service for members will be tolerably complete. A new printing contract, entered into at the beginning of the year, enabled the Committee materially to improve the financial position of the *Journal*, and as a somewhat better contract has been made for 1933, no serious apprehension on the score of finance, so far as the *Journal* is concerned, is now felt.

The *Journal* Staff has continued to contribute to the general services of the Institute through the Library and Information Bureau to which members are definitely referring more and more frequently.

Sales and subscriptions continue on a satisfactory scale, and the revenue from Advertisements, having definitely increased, justifies the Committee's action in appointing an Advertisement Representative.

Institute Diplomas

As forecast in the last report, revised Regulations governing the award of the Associateship and Fellowship have been issued. The Regulations now provide for the Examination in relation to Associateship applications to comprise two parts—Part I (Auxiliary Subjects) and Part II (General Textile Technology). Part I has been created in order to meet the requirements of applicants whose attainments in general education are inadequate. Since the issue of the revised Regulations, the Selection Committee has responded to overtures emanating from technical colleges and schools with regard to the fulfilment of the regulation concerning the occupational experience of applicants. Provided all other requirements for reference to the Examination have been met, approved applicants may now take the Examination and qualify later as to occupational experience.

Applications during 1932 totalled 50 (6 Fellowship and 44 Associateship), as compared with 53 in the previous year (9 Fellowship and 44 Associateship), and 69 (15 Fellowship and 54 Associateship) in 1930. The total number of applications received since the inauguration of the scheme in 1925 is 686 (260 Fellowship and 426 Associateship). The Examination in relation to Associateship applications is now only held once instead of twice each year. In 1931 there were 22 candidates in June and 21 in December. For the 1932 Examination in June, held at Manchester, London, and Dunfermline, there were 22 candidates in all, and 15 of this number passed.

Annual Competitions

In relation to the design and structure of woven fabrics, the Competitions Committee has given close attention to the revision of conditions in order to meet changed circumstances. Recent revision appears to have proved beneficial. The total entries for the year reached 82 as against 52 in 1931. For the first time, a competition in respect of knitted fabrics was available, and the response was sufficient to induce continuance. Council has also sanctioned the inauguration of a competition in respect of Designs for Printed Fabrics for the current year. The Yarns Competition will be continued, and in this connection the Council appreciates the gift of £5 for three years on the part of Messrs. R. Greg & Co., of Reddish. It is felt that the Institute has considerable claim for recognition in the form of similar gifts. The matter is becoming one of urgency, for the reason that the annual yield from the Crompton Memorial Fund for competition purposes is reduced owing to the lessened rate of interest on the investment.

Council and Committee Meetings

The following is the record of meetings during 1932—Council, 10; Finance and General Purposes, 10; Selection, 10; Publications, 11; Library, 1; Competitions, 3; Scholarships, 2; Dictionary and Fabrics Collection, 1; Lancashire Section, 1; London Section, 2; Midlands Section, 1; Yorkshire Section, 2; Irish Section, 1; Scottish Section, 2; total 57, as against 72 in the previous year. In addition to the foregoing, four sub-committees met for the consideration of special matters.

Section Meetings and Lectures

Four meetings of the Lancashire Section and two joint meetings; two of the Yorkshire Section; six London Section; one Irish Section; three Midlands Section (and three visits); and one Scottish Section, took place during 1932, at which papers were read and discussed.

Membership

The membership list at the end of 1932—to be carried forward to 1933—was made up as follows—Honorary Members, 7; Life Members, 35; Ordinary Members, 1,250; Junior Members, 136; total 1,428, as against 1,443 at the end of 1931. Of the members at 31st December last, 167 had been admitted to the Fellowship and 261 to the Associateship.

The totals for the foundation year (1910) and other years named were—1910, 233; 1921, 904; 1925, 1,275; 1930, 1,542; 1931, 1,443.

The Council laments the loss by death during 1932 of many prominent members, including the following—F. Arrowsmith (Manchester); W. H. Bell (Bolton); A. Chadwick (Rochdale); Oscar S. Hall (Bury); G. C. Haworth (Manchester); C. W. Law (Manchester); F. Moc (Czechoslovakia); J. Shaw (St. Annes-on-Sea); J. H. Stubbs (Manchester); Mark Sutton (Manchester and Rio de Janeiro); E. F. Wyrill (Australia); R. H. Wilmot (Leicester).

Since the beginning of the present year, losses by death have been exceptionally heavy. The demise of Mr. William Howarth, of Bolton, Past-President of the Institute, whose efforts for the establishment of the Institute Scholarships resulted in the inauguration of a permanent scheme, was profoundly regretted. Other deaths recorded this year include the following—W. Cunliffe (Liverpool); W. F. Edwards (U.S.A.); and James Abbott (Manchester).

TREASURER'S REPORT

Mr. T. Fletcher Robinson, who presented the annual accounts for 1932, together with the balance sheet, said that he was sure members would regret the absence through illness of the Honorary Treasurer, Mr. W. W. Lishman. As his predecessor, and Treasurer over a number of years, it gave him pleasure to perform the duty of presenting the accounts and to draw member's attention to the fact that a deficit in the Revenue Account for 1931 had been turned into a credit balance in the same account for 1932.

The Treasurer's report, Auditor's report, accounts, and balance sheet were moved, seconded, and duly adopted. They follow—

1931		LIABILITIES		£ s. d.		£ s. d.		ASSETS		£ s. d.	
143 15 0	Subscriptions paid in advance	...	...	131 14 6	Cash at Bank—Foundation Fund	...	...	164 4 5		
42 13 11	Life Membership Subscription Account—	...	...	42 13 11	Cash in Hand	...	...	25 12 6		
	Balance as on 31st December 1931	...	...	8 10 10	Sundry Debtors—	...	...		
	Less 10% of £85 8s. 1d. transferred to Subscrip-	...	...		Journal Account—	...	...		
	tions Account	...	...	34 3 1	Outstanding Adverts.	...	...	306 1 6		
2500 0 0	Sundry Reserves, viz.—	...	...		Outstanding Reprints	...	...	35 6 8		
298 0 0	Crompton Prize Fund	2500 0 0			Outstanding Grant Rug Yarn Association	...	...	—	
97 10 0	Life Membership Reserve Account	319 0 0			Chronological Record—Outstanding Adverts.	...	...	—	
10417 2 6	Perpetual Membership Reserve Account	10576 10 5			Furniture, Fittings, and Library Account—	...	...	512 6 9		
5000 0 0	Foundation Fund	5000 0 0			Balance as on 31st December 1931	...	...	32 11 0		
881 9 6	Do. (Cotton Reconstruction Board Grant)	881 9 6			Additions during year	...	...	544 17 9		
250 0 0	Do. (Diplomas Account)	250 0 0			Less Depreciation	...	...	72 16 0		
	Do. (London Section Reserve Account)			130 4 9 11	London Furniture Account—	...	...	472 1 9		
48 9 10	Competition Scheme—Income and Expenditure	...	...		Balance as on 31st December 1931	...	...	32 0 11		
411 3 0	Account Balance	25 8 1			Less Depreciation	...	...	4 0 1		
462 12 2	Scholarship Scheme Reserve Account	287 2 5			Gas and Electricity Deposits	...	...	28 0 10		
686 16 7	Sundry Creditors and Reserves as per list	338 6 3			Stock of Chronological Records, etc. (estimated value)	...	...	90 10 0		
	Bank Overdraft—General Account	741 0 8			Investment Account (see Schedule)—	...	...	90 16 11		
					Foundation Fund	...	...		
					Crompton Prize Fund	...	...	16515 14 0		
					Life Membership Account	...	...	2500 0 0		
					Perpetual Membership Account	...	...	105 0 0		
					Office and Rooms Alteration Account—Balance	...	...	97 10 0		
					Revenue Account—	...	...	19218 4 0		
					Balance as on 31st December 1931	...	...	43 11 1		
					Less Excess Income over Expenditure for Year	...	...	913 12 2		
								143 16 11			
£21250 12 6		£21163 4 11		£21250 12 6		£21163 4 11		769 15 3			

NOTE—There is contingent liability for Income Tax in respect of final agreement of assessments for 1926-27 to 1932-33 inclusive

NOTE—There is contingent liability for income tax in respect of final assessments for 1926-27 to 1932-33 inclusive

AUDITORS' REPORT TO MEMBERS

We report to the members that we have examined the above Balance Sheet, together with the books and vouchers of the Institute, and that we have obtained all the information and explanations we have required. We further report that in our opinion the Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Institute's affairs according to the best of our information and the explanations given to us, and as shown by the books of the Institute.

W. W. L. LISHMAN *Hon. Treasurer.*
H. BINNS *Chairman of Council.*
W. FROST *Chairman, Finance Committee*

3rd March 1933
37 York Street, Manchester.

(Signed) ARTHUR E. PIGGOTT, SON & SOUTHWORTH
Incorporated Accountants, Auditors.

Dr. The Textile Institute—Revenue Account for the Year ended 31st December 1932 Cr.

EXPENDITURE				INCOME			
1931	£	s	d	1931	£	s	d
To Rent and Rates—Manchester	178	12	5	By Membership Subscriptions—			
Less to Journal Account				1168 Members at £2 2s			
				2 Members at £1 1s	2494	16	0
" Salaries	6850	0	0	15 Members at £1 1s (half year)			
Less to Journal Account				97 Junior Members at £1 1s	15	15	0
" Wages	246	0	8	9 Junior Members at 10s 6d (half year)	101	17	0
Less to Journal Account				Life Members—10% of Balances	4	14	6
" Heating, Lighting, and Cleaning				Subscriptions in Advance as per Balance Sheet	8	10	10
Less to Journal Account				31st December 1931			
" Officers, Canteen, and General Expenses	66	0	24	Subscriptions in Arrear paid during 1932	143	15	0
" Postages, Telegrams, and Telephones	113	2	4	Interest from Diplomas, Life Memberships, and	90	5	3
" General Printing and Stationery	152	17	3	Perpetual Membership Investments	52	5	10
" Insurances	6	16	11	Special Subscription—The Weavers' Company	21	0	0
" Audit Fee and Legal Charges	89	2	0	Diploma Fees	132	0	0
" Subscriptions to Institutions	5	5	0				
" Library Account	54	13	7		3067	1	5
" Section Expenses—					1073	9	9
London (including Office and Rooms)	185	7	6	Less Amount transferred to Journal Account			
Lancashire	17	8	7	" Crompton Fund Administration Expenses			
Yorkshire	36	18	2	" Foundation Fund Income from Investments Account			
Scotland	20	11	4				
Ireland	6	15	0				
Midlands	5	10	2				
					2049	18	6
					20	0	0
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					2069	18	6
					734	18	94
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SUBSCRIPTIONS—

TOTAL ARREARS at 31st December 1932

ARREARS written off

Total Arrears Current

£424 17 0

101 9 0

£323 8 0

Audited and found correct,

3rd March 1933

37 York Street, Manchester

ARTHUR E. PIGGOTT, SON & SOUTHWORTH

Incorporated Accountants, Auditors.

£2279 15 3

Dr. The Textile Institute—Journal Account for the Year ended 31st December 1932 Cr.

EXPENDITURE			INCOME		
1931	£	s d	1931	£	s d
2856 17 0	To Printing, Reprints, and Postages (Dt. tribution)		10 10 0	By The Clothworkers' Company—Annual Donation	10 10 0
82 4 0	" Literary Contributions and Abstract		1757 11 2	" Advertisements and <i>Journal</i> Subscriptions	1940 18 7
653 16 0	" Salaries	2395 16 4	163 2 6	" Linen Industry Research Association— <i>Journal</i> Subscriptions	180 10 0
104 2 6	" Wages	64 16 1	295 8 3	" Reprints	215 13 0
75 5 2	" Postages, Telegrams, and Telephone	116 10 10	1103 16 1	" Transfer from Membership Subscriptions	1073 9 9
42 17 0	" Stationery, Binding and <i>Journal</i> , is purchased	73 14 10	482 14 6	" Transfer from Foundation Fund Income from Investments Account	230 8 6
56 4 3	" Advertisement Commission	9 16 7			
12 13 7	" Travelling Expenses	174 15 11			
89 6 2	" Rent and Rate (Proportion)	32 5 3	3813 2 6		
34 14 1	" Heating, Lighting and Cleaning (Proportion)	48 15 7	194 17 3	Revenue Account /1931	3630 19 10
		32 6 1			
£4007 19 9		£3630 19 10	£4007 19 9		£3630 19 10

The Textile Institute—Crompton Prize Fund Scheme : Competitions Income and Expenditure Account for Year ended 31st December 1932

Income and Expenditure Account for Year ended 31st December 1932										Cr.				
Dr.	EXPENDITURE					INCOME					£ s d			
	1931 £	s	d			1931 £	s	d						
	32	15	11	To Printing and Stationery		63	1	10	By Balance brought forward	69	9	10		
	30	11	10	" Purchase of Specimens	27	2	1		" Albums—Subscriptions	139	1	0		
	5	4	6	" Mounting of Specimens	49	19	6		" Competition Entrance Fees	11	4	0		
	167	4	6	" Prize Awards and Expenses	16	19	9		" Dividend on £1000 5% War Stock	£50	0	0		
	8	6	3	" Postages and Carriage	158	19	9		" Dividend on £1125 4% L M S Railway Stock	24	15	0		
	20	0	0	" Administration Expenses	11	5	8							
	20	0	0		20	0	0							
	264	3	0											
	69	9	10	" Balance carried forward	279	6	9	46	2	6	Income Tax Repayment	11	5	0
					26	8	1							

Audited and found correct,
3rd March 1933

37 York Street, Manchester

ARTHUR E. PIGGOTT, SON & SOUTHWORTH
Incorporated Accountants, Auditors.

Dr. The Textile Institute—Foundation Fund Income from Investments Account for the Year ended 31st December 1932 Cr.

EXPENDITURE				INCOME			
1932		£	s. d.	1932		£	s. d.
May 20	To Mather Lecture			Feb. 1	By Dividend—£1242 10s. 4% Consolidated Stock less tax	18	0 4
Dec. 31	" Interest on £244 9s. 2d. 5% War Stock (Diplomas)		25 0 0	Mar. 1	" " £1000 4% Funding Loan 1960-90, less tax	18	0 0
" 31	" Interest on £102 5s. 5% War Stock (Life Members)	42	4 6	June 1	" " £15939 18s. 10d. 5% War Stock 1929-47	388	0 0
" 31	" Interest on £98 1s. 6d. 5% War Stock (Perpetual Mem- bers) transferred	5	2 3	Aug. 1	" " £1242 10s. 4% Consolidated Stock less tax	18	0 0
" 31	" Interest on £240 5% War Stock (London Section)	4	19 1	Nov. 1	" " £15939 18s. 10d. 5% War Stock 1929-47	388	0 0
" 31	" Interest on £4870 5% War Stock (Scholarship) trans- ferred	12	0 0	Dec. 1	" " £1242 10s. 4% Consolidated Stock less tax	18	0 0
" 31	" Interest on £1000 5% War Stock (Crompton) transferred	243	10 0	" 9	Returned Commission on War Stock Conversion	388	9 11
" 31	" Journal Account		357 15 10			15	15 0
" 31	" Revenue Account		230 8 6				
			286 3 7				
			<u>£879 7 11</u>				

Dr. The Textile Institute—Scholarship Scheme Income and Expenditure Account for the Year ended 31st December 1932 Cr.

EXPENDITURE				INCOME			
1932		£	s. d.	1931		£	s. d.
Dec. 31	To Scholarship Holders' Maintenance Allowances— Alan Ratcliffe	182	6 6	Dec. 31	By Balance brought forward...	411	3 0
" 31	" William Graham	115	9 3	1932	" " Refund of Breakage Deposit—College of Technology	...	...
" 31	" College Fees	297	15 9	Dec. 31	" " Interest on £4870 5% War Stock 1929-47	1	18 2
" 31	" Postages	70	8 0			243	10 0
" 31	" Balance carried forward	369	8 9				
		287	2 5				
			<u>£656 11 2</u>				

Audited and found correct,
3rd March 1933

3rd York Street, Manchester.

ARTHUR E. PIGGOTT, SON & SOUTHWORTH
Incorporated Accountants, Auditors.

INSTITUTE FOUNDATION AND OTHER FUNDS

SCHEDULE OF INVESTMENTS

(at Cost or Value at original date of gift) as on 31st December 1932

Foundation Fund—

	£	s.	d.	£	s.	d.
£3737 14 9 3½% War Loan	3503	7	0			
£4789 9 5 Do.	4789	9	5			
£ 48 16 3 Do.	49	14	1			
£ 105 5 3 Do.	106	14	0			
£ 102 17 6 Do.						
£4870 0 0 Do. (Scholarship Scheme)	5355	0	0			
£ 240 0 0 Do. (London Section)... ..						
£ 650 0 0 Do. (Diplomas)	661	9	6			
£ 194 9 2 Do. (Diplomas)	200	0	0			
£1000 0 0 4% Funding Loan 1960-90	800	0	0			
£1242 10 0 4% Consolidated Stock	1050	0	0			
				16515	14	0

Crompton Prize Fund—

£1000 0 0 3½% War Loan	1000	0	0			
£1125 0 0 4% L.M.S. Railway Preference Stock	1500	0	0			
				2500	0	0

Life Membership Account—

£ 52 5 0 3½% War Loan	53	14	6			
£ 50 0 0 Do.	51	5	6			
				105	0	0

Perpetual Membership Account—

£ 99 1 6 3½% War Loan				97	10	0
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£19218 4 0

The Market Value of the above securities on
31st December 1932 was approximately £18491 14 0

(Securities at National Provincial Bank Ltd.)

Audited and found correct,

3rd March 1933

37 York Street, Manchester.

ARTHUR E. PIGGOTT, SON & SOUTHWORTH
Incorporated Accountants, Auditors.

ELECTION OF PRESIDENT



SIR WILLIAM CLARE LEES, O.B.E., J.P.
Elected President of the Textile Institute, May 1933

In proposing the election of Sir Wm. Clare Lees, O.B.E., as the new President, Mr. George Garnett said he had been thinking of the past two years. "I have come to realise," he said, "that there is a magnificent band of men associated with this Institute whose efforts have helped it to maintain its progress, to maintain and enhance its prestige, and, in addition to secure the unique position that it has balanced its finances for the year".

Membership had slightly declined; there had been resignations, but in spite of the depression there had been accretions. Considering the depression in the industrial world he thought the progress of the Institute had been really marvellous. He thought they should be proud of the position which the Institute occupied to-day. They were offering youth to-day splendid opportunities to qualify for the call that would be made upon them in

years to come for the management, the staffing, and the running of our great textile industry.

He had been particularly pleased to follow the *Journal* of the Institute. There, again, they had evidence of the quality of the work done by the Publications Committee. He paid this tribute to the chairman and members of the Committee because it was the backbone of the progress the Institute had been making.

As President, continued Mr. Garnett, he felt he had done far too little. He came into the office with a certain amount of trepidation, feeling he was not the right man, but his sympathies with the work had been and still were quite keen. He looked back with a certain amount of regret during the past two years because on account of the dreadful time through which they had been passing there had not been opportunities for doing what he would like to have done. He appreciated the honour that had been bestowed upon him. In future years he would be glad to be of service again.

The industrial outlook at the present time was causing serious concern. He believed that our management and our designers were well equipped educationally for their position, and equal to any call that might be made upon them. It was not in their hands alone to guide the industry in the future. They were suffering to-day from the colossal decline in values due to the monetary collapse, starting in America in 1929, the complete loss of confidence, and the serious disequilibrium in the industrial position in different parts of the world.

Arising out of that collapse was fear of what ultimately might arise. As a consequence, the trading nations of the world forthwith restricted their industrial activities, and the chaos of tariff barriers, restrictions of exchange, quotas, subsidies, etc., were the outcome of fear, suspicion, and disturbance. It was his judgment that the first thing that would have to be tackled was the international position of the value of money. It was only by the restoration of exchanges on some agreed value that they could hope to see a resumption of a freer flow of trade that would not only fill our factories with more work, but with work at profitable prices.

It was with peculiar pleasure he proposed the election as President of Sir William Clare Lees, a managing director of the Bleachers' Association, not only for his valued industrial connection, but because of his own personality, position, and outlook. He had the drive, personal push, and quality of mind that in the past had always been associated with Presidents of the Institute. They looked forward, under his guidance, to maintaining the quality of work being carried on and assured him at all times of their most cordial support and collaboration.

Mr. Frank Wright seconded, and said they had been fortunate in their Presidents, and in this connection he particularly wished to mention the late Mr. William Howarth. It was a source of great pleasure to know they were going to have a President whose knowledge was so wide and to whom they could look for guidance. He could assure Sir William that of all the organisations with which he had been connected, there were none of which he would have cause to feel prouder than of the Textile Institute. There were members present who had done great work for the Institute. He was impressed with the amount of time and attention voluntarily given by them.

The election was carried unanimously.

Sir William Clare Lees, in reply, said he was proud to stand in that position. He realised that he was following distinguished leaders, particularly their last President. He did not know whether it was the rule to oscillate between Lancashire and Yorkshire, but at any rate he felt he was following one who was held in high regard not only in Lancashire, but, what was a little more difficult, in his own county.

"The first thing that strikes me," continued Sir William, "is that here you are controlling and working for the technical education of men destined to control the largest proportion of the exports of this country. Textile exports, even with all the present difficulties and trouble, amount to £100,000,000 a year. The cotton exports are more than half at £62,800,000, wool £24,800,000, linen £5,800,000, silk £1,000,000, artificial silk £3,000,000, and other textile materials £3,500,000. The total is a serious diminution compared with pre-war, for textile exports in 1913 were £180,000,000. Still, of the formidable and splendid total of £100,000,000 to-day we have a great and grave responsibility in this Institute to see that those who direct that vast output are technically highly educated.

"Looking to the future," continued Sir William, "there does not appear to be any reason for supposing that the development of the activities of this Institute may not proceed as satisfactorily as in the past. The Institute has been fortunate in securing the enthusiastic services of several bodies of members to promote its principal activities. In regard to the advancement of textile technology, its diplomas are calculated to exert an influence of enormous benefit on the whole industry. Formerly, trainees of our technical colleges and schools had no such organisation to offer incentives to continuance of study, but now this Institute not only provides the opportunity but certifies attainment. One of the leading objects contained in the Charter of the Institute is—

"To secure for the benefit of the trading communities interested in textiles and for the benefit of the general public a well-defined and publicly-recognised class of persons well qualified to be employed as experts in textile technology and to undertake the important duties of advising upon or directing or controlling the consideration of textile problems or operations and to occupy posts of public and commercial importance in connection therewith."

"The scheme of qualification is most definitely contributing to the realisation of this object. Furthermore, it is influencing the course of technical education in the colleges and schools in the various textile centres of the country. At the present moment, plans are in course of preparation with a view to the establishment of national certificates in textiles. These certificates have been in existence for some considerable time in relation to subjects such as chemistry, electrical engineering, mechanical engineering, building, etc. They are promoted by the

Board of Education conjointly with the professional body specifically concerned with the subject. Similar procedure is contemplated in regard to textiles, and if the scheme materialises with the approval and support of the City and Guilds of London Institute, then a higher standard of attainment in textile technology will be possible in the earlier stages of training.

"The Employment Register of the Institute has already received encouraging attention on the part of employers with vacancies at their disposal, and it may be confidently anticipated that owing to the rigorous tests applied for admission to the Associateship of the Institute, the Register will be increasingly utilised.

"The examination in connection with applications for the Associateship is now fully established and it is important to remember that candidates are not admitted unless already in possession of well recognised qualifications. The Institute qualifications are therefore essentially of post-graduate character.

"The Institute now has a programme of well established activities, and if there were no addition for some years to come there is abundant opportunity for the services of the members in the maintenance and consolidation of the position attained.

"So far as cotton and artificial silk is concerned the main trouble is Asiatic. The enormous rise in the rate of duty charged upon our goods going into India has caused a great increase in Indian mill production with a corresponding decrease in our exports. This alone would have been a serious factor, but simultaneously with this movement, there has been the persistent growth of Japanese production and export, which coming at the same time as the reduction in our exports to India, has created a situation so grave in its ultimate implications for this country that it is ceasing to be a Lancashire problem and is rapidly becoming a national problem. The preservation of our largest export trades, the employment of a considerable proportion of our population, the preservation of an important share of the capital and wealth of the nation are in jeopardy. The competition is not a fair one from this country's point of view. It is a battle of standards of living; a battle between the low standards of the East and the higher standards we have established.

"This is not the time or place to discuss this matter in detail," said Sir William, "but in my opinion, Government action, wherever we have the power to act, should be immediately taken in order to preserve those markets, over which we exercise control, for British goods in exchange for the raw materials and foodstuffs which we take from them. Action, and action *now* is what is wanted. The notice which has been given to terminate the existing treaty between Japan and West Africa is a first step in the right direction. We shall have to take similar action in many other quarters if we are to hold what we already possess.

"There is a general consensus of opinion that the world depression is mainly attributable to the disastrous fall in the prices of primary products, but there is a wide divergence of opinion as to the fundamental causes which have forced those prices down to such low levels. One school of thought says it is due to monetary causes. Another that it is due to over production; and yet another would tell you that it is due solely to under consumption.

"I propose to examine one or two aspects of this question this afternoon. The great break in industrial activity came after the collapse in America in 1929, but, even in 1929, prices of primary products had been steadily settling down for five or six years previously. In fact, from figures in the *Economist*, prices over a given group of primary products had fallen from 100 (which might be taken as the basis figure for 1923 to 1925 average) to 69 in the year 1929, when the American speculative boom came to an end. This trend of prices was a perfectly natural one arising from the actual facts and circumstances. Stocks of the same group of commodities were nearly double in 1929 what they were in 1923-25. Since 1929 the accumulation of stocks has been at a much slower rate. Stocks at the end of 1932 were only 30% greater than they were in 1929, though that

percentage was on the larger basis figure which had been built up between 1925 and 1929. To-day stocks are no higher in this group of commodities than they were in 1931, though during the early part of last year they rose somewhat, and then fell away again. But, in spite of the fact that world's stocks of these commodities have been stable since 1931, prices have continued to fall under the pressure of those stocks which had accumulated in previous years, with the result that the value of these commodities which was equal to 100 in 1923-25, stood at 26 at the end of 1932. No wonder the purchasing power of these primary producing nations has been to a large extent eliminated, and their ability to pay their external indebtedness brought into jeopardy.

"Turning to the question of industrial production," continued the President, "there is no evidence that the fall in prices has been due to over production. Rather is it due to an excess of productive capacity which is always standing waiting for a volume of business definitely too small to occupy it full time. It is this surplus capacity in every section of the textile industry which is causing such disastrously low prices to be taken, and not any accumulation of stocks made in anticipation of business which has not matured. Looking at the problem from a world point of view for all types of mechanical production, a statement issued in the *Board of Trade Journal* recently, shows that the industrial production of the principal nations of the world, leaving Japan out of the picture for the time being, has shrunk by 33%. It is quite clear, therefore, that with an ever-increasing population there has been no over-production of manufactured goods generally speaking, but that this reduced output has its origin in the low purchasing power of primary producers all over the world.

"We have then a picture of active industrial production up to 1929, with the menace of steadily increasing stocks of primary products in the background. Then came the American speculative boom, and subsequent collapse. Confidence was shaken, and in the effort to sell the growing crops, the dead weight of accumulated stocks was added to the volume available for sale. The growing crops were large enough to satisfy world requirements, and so the pressure of these stocks has continued from harvest to harvest, always having an increasing effect in a downward direction. Until these stocks are materially reduced, there is no great likelihood of an important increase in the price of primary products.

"Signs, however, are not lacking that a turn in the tide in this respect is taking place, and it seems probable that throughout the present year stocks in many cases will be reduced, and that world consumption will be in excess of this year's production in more than one important group of commodities. There is plenty of credit to finance the world's trade if confidence be restored. A marked increase in the price of world commodities is the only means of restoring world confidence at the present time. When that is accomplished, credits will be unfrozen, payments will be made possible, and international trade will once more be restored to its former dimensions, but some regulation between supply and demand in primary products is obviously necessary in this age, when farming has been completely mechanised, and the production of crops in areas formerly deemed unsuitable has been made possible by seed selection and the results of research in other directions.

"Watch stocks of primary commodities," said Sir William. "When you see these steadily falling—and there is fortunately a prospect of a diminution this year and probably a continued diminution the year after—then you may rest assured that a foundation is being established on which there will ultimately be built a restoration of the trade in the world. Foolish Government interference in respect of more than one commodity has detained the recovery by one or two years. The process of recovery is already visible in more than one direction.

"I think we in this country should try to realise what has been the experience of other countries. We in this country have developed an inferiority complex,

and it is this attitude of mind we ought to get rid of. Compare the position in this country in 1931, when we took two great decisions, whether rightly or wrongly—the change in the monetary policy by going off the gold standard and a change in the fiscal policy by becoming a protective nation. These two processes are indissolubly mingled together in their effects on the economic life of this country. It is well to turn back and look at events in this and other countries. You will find that the volume of internal mechanical production as a whole in some countries has gone down since 1929 to the end of 1932 to an extent ranging from 30% in some countries to 45% in others, while our volume has gone down only 16½% in the same period. If you take France, Germany, Holland, and Czechoslovakia, countries which threatened us industrially, from 1925–31, you will find their export trade has gone down 35% to 40%, and in Czechoslovakia it has gone down as much as 46%. Our export trade in the same period has only gone down 7%, and therefore it is clear from these figures that we enjoyed a greater proportion of the world's internal trade of the world than before we changed our monetary and fiscal policy. During this time we have established the position as far as this country is concerned, that we have gone but little worse, while other countries have gone materially worse in the same period. Therefore, we can take hope that when world conditions are re-created, and when the volume of the external trade of the world is increased to a material extent, we shall be in a more competitive position than we have been for some time and shall be able to enter into a full share in the increased and upward tendency of world trade. I think in this difficult time, when everybody is suffering in one direction or another, it is well to look at these basic facts and take comfort from them."

Mr. W. Frost moved and Mr. G. H. Thompson seconded a vote of thanks to Mr. Garnett for his work during the past two years, which, Mr. Frost emphasised, had been beneficial to the Institute.

Messrs. F. Nasmith, F.T.I., W. Turner, F.T.I., and W. H. Webb, F.T.I., were re-elected Vice-Presidents.

Mr. Athey announced the result of the ballot for the election of ten members for the Council. The following were elected—Messrs. F. W. Barwick (Manchester), J. C. Withers (Manchester), W. E. Morton (Manchester), H. Bromiley (Bolton), W. T. Boothman (Bolton), W. Kershaw (Manchester), S. Watson (Hyde), W. B. Crompton (Bispham), H. Jaques (Bradford), and S. Kershaw (Bradford).

Messrs. Arthur E. Piggott, Son & Southworth were re-elected Auditors.

SCOTTISH SECTION ANNUAL MEETING

The Annual Meeting of the Scottish Section was held in the North British Station Hotel, Edinburgh, on Friday, 28th April 1933, when Mr. J. Macpherson Brown presided over a representative attendance.

After intimating apologies for absence from Messrs. D. Baird, R. Baird, A. R. Geary and T. M. Lees, the Hon. Secretary read the Minutes of the previous Annual Meeting as printed in the *Journal* and already circulated to members.

The Chairman welcomed those present, and reviewed the Section's activities during the last session. Owing to various unfortunate circumstances, certain provisional arrangements had not been carried out as expected, and the Committee hoped to make up for that by arranging an earlier programme of meetings for the coming season.

The Chairman congratulated Mr. Robbie (Dundee) and Mr. Greenwood (Glasgow) on their election as Associates of the Institute.

The Hon. Secretary submitted a report of the membership at 20th February, there being 88 members, a decrease of one on the previous year. Six members have been lost through resignation, while there were two new members and three transferred from other Sections. The membership was distributed as follows—West and South-west 31; East and Midlands 28; Border District, including Carlisle 26; North 3.

In addition to the Annual Meeting, two other Section meetings had been held, viz., Grangemouth and Galashiels.

The Hon. Secretary submitted financial statement showing total expenses of the Section averaging just over 9½d. per member, and pointed out that the principal items referred to rent of rooms for the annual meeting. The Chairman expressed the Committee's thanks to the Hon. Secretary for his work during the year, and expressed satisfaction at the very reasonable outlay which had been incurred. He suggested that consideration might be given to a more ambitious programme up to the maximum expenditure allowed by headquarters.

The following members were elected to form Section Committee—Messrs. J. P. Beveridge, A. W. Blair, T. M. Lees, S. Roberts, A. Smith, and Dr. A. W. Stevenson.

The Chairman welcomed Mr. J. D. Athey (General Secretary) who was in attendance, and in response to a request, Mr. Athey commented upon the forthcoming Harrogate Conference and hoped that there would be a representation from the Scottish Section. He also referred to the facilities afforded by the Institute's Information Bureau and suggested that members might take fuller advantage of this.

Dr. A. W. Stevenson proposed a vote of thanks to Messrs. J. M. Brown and A. R. Geary on retiring from Section Committee, and this was heartily accorded.

Thereafter the meeting discussed various suggestions for future meetings and works visits, and the Secretary was instructed to bring the suggestions before the first meeting of the Section Committee.

Mr. J. P. Beveridge suggested the formation of Textile Societies in different parts of the country and suggested that these might be useful in bringing forward young members for the Institute. After some discussion, it was remitted to the Committee to consider the matter, although it was felt that while the Institute could encourage and assist such societies, it would be unwise to proceed with arrangements in the absence of a spontaneous desire from the different districts themselves.

The meeting adjourned for tea and at 6.30 p.m. Mr. John Davidson, Edinburgh Manager of the Royal Insurance Co. addressed the members on "Fire Precautions and Insurance in Textile Factories." A very interesting discussion followed, and on the motion of Mr. J. P. Beveridge, a vote of thanks was accorded to the speaker for his instructive address.

MIDLANDS SECTION ANNUAL MEETING

This Annual Meeting was held at the College of Technology, Leicester, on the evening of Wednesday, 10th May 1933, when there was a representative gathering of members. Mr. T. Morley presided.

The record of the proceedings of the previous Annual Meeting was read and approved.

Hon. Secretary's Report—Mr. Chamberlain reported that the membership of the Section at time of compilation of his report reached 102 whilst four or five had since been added. There had been 17 members elected or transferred from other Sections during the year, whilst 11 had either resigned or been transferred. The complete record showed a slight increase on the year. The demise of Mr. R. H. Wilmot, M.Sc., was deeply deplored.

The programme arranged was carried out in its entirety. Four Lectures were given—two at Nottingham and two at Leicester—and three visits were made, viz., to the Textile Exhibition at Leicester where the members were entertained to lunch by the promoters, to Messrs I. & R. Morley's Silk Throwing and Silk Hose Factory at Sutton-in-Ashfield and to Messrs. A. W. Swann & Co. Ltd., Leicester. The address promised by Mr. A. Wilfred Swann was not given, owing to unavoidable absence. One of the lectures was attended by the Midland Members of the Society of Dyers and Colourists and another by the Members of the Leicester Textile Society. The actual number of members at the lectures was small, not more than 20 members attending any lecture except at the Textile Exhibition when about 30 members were present, but as these lectures were either of a joint character or open the attendance was quite good. About 25 members attended the visit to Messrs. I. & R. Morley's but only 12 went to the works of Messrs. A. W. Swann. The Hon. Secretary wished to thank the Chairman and Committee for the way they had assisted and Mr. S. E. Ward and Mr. E. Wildt for their services as judges in the Knitted Fabric Competition. For three years, he (Mr. Chamberlain) had acted as Secretary *pro tem* and he had now tendered his resignation. He would continue to serve the Institute, however, to the best of his ability.

The report was adopted and on the motion of Mr. Swann, seconded by Mr. Wildt, Mr. Chamberlain's resignation as Hon. Secretary was accepted on the understanding that he would continue to assist. Mr. Chamberlain was also heartily thanked for his services over the past three years.

Moved by Mr. Wildt, seconded by Mr. Bentley, it was resolved that Mr. T. A. Purt (Leicester) be appointed Hon. Secretary.

Programme of Lectures and Visits—Discussion under this heading followed and it was decided to arrange for three lectures and three visits during next session. It was agreed to accept Papers by Mr. A. W. Swann, Mr. Wm. Pritchard (Textiles in relation to the requirements of the Railway Company) and Mr. J. K. Ebbelwhite; also to contemplate visits to the works of the Dunlop Rubber Co. (Birmingham), to a carpet factory (Kidderminster) and to a mill (probably at Matlock). Details of arrangement were referred to the Hon. Secretary and Committee.

Election of Committee—It was unanimously decided that the following members be elected the Section Committee for the ensuing year, subject to approval of the Council of the Institute—Messrs. T. Morley, J. Chamberlain, Herman S. Bell, P. A. Bentley, W. N. Bignall, H. F. Lilburn, T. A. Purt, A. Stoppard, E. Millson Walker, S. E. Ward, E. Wildt, W. Pritchard, F. Hern, and J. K. Ebbelwhite.

The meeting closed with an expression of thanks to the Chairman.

IRISH SECTION ANNUAL MEETING

The 7th Annual Meeting of the Irish Section of the Textile Institute was held at the Municipal College of Technology, Belfast, on Thursday, 6th April 1933, Mr. S. C. Carse being voted to the Chair. The Hon. Secretary (Mr. F. J. W. Shannon) presented the Annual Report which stated that during the past session two meetings were held at which papers were contributed—9th December 1932: "The Swelling of Cellulose in Caustic Alkalis" by S. M. Neale, M.Sc., and 26th January 1933: "Electricity and its application in Textile Works" by R. H. Friend, A.M.I.E.E. A third meeting was arranged for the end of March at which Dr. Hampson, Director of the Launderers' Research Association, had promised to give a paper. Owing to illness, however, Dr. Hampson asked to have the meeting put back to a later date and it was eventually decided to postpone this lecture until the beginning of next session. During the year, four new members were added and there were two resignations. The membership of the Section now stands at 35. Thanks were due to Mr. Neale and Mr. Friend for papers contributed and to Prof. Earls for facilities afforded as to holding of meetings at the College.

On the proposition of Mr. Cowden, seconded by Mr. Kirkwood, the report was adopted.

With regard to the election of office-bearers, Mr. Shannon said that owing to illness and an increasing demand in business he had not the necessary time at his disposal and he suggested a change in the secretaryship.

The Chairman and others paid tribute to the work of the Hon. Secretary during past years and requested that Mr. Shannon should allow his name to go forward for another year. Meantime they would approach one or two members who would be likely to take over the Office.

It was then decided to put forward the following nominations for election for the ensuing year—Chairman, Mr. W. H. Webb (Randalstown); Hon. Secretary, Mr. F. J. W. Shannon; Committee, Dr. Gibson, Prof. Bradbury, Messrs. W. J. Cowden, J. Kirkwood, and S. C. Carse.

A discussion took place with regard to lectures for the following session and it was decided to have Dr. Hampson's paper in November if convenient. Prof. Bradbury suggested that Mr. Wigglesworth might be persuaded to give a lecture on the "Selby Flax Processing," which—along with Courtrai retting—he understood was illustrated by cinematograph. The Hon. Secretary was instructed to put the suggestion before the General Secretary.

FEDERATION OF TEXTILE SOCIETIES AND KINDRED ORGANISATIONS' ANNUAL MEETING AT OLDHAM

By invitation of the Oldham Technical Association and Old Students' Union, and in celebration of the majority attainment of this organisation, the annual meeting and conference of the Federation of Textile Societies and Kindred Organisations took place at Oldham on Saturday, 6th May, when about 100 delegates, representing societies in Lancashire, Yorkshire, Midlands, and Belfast, attended. In the morning, visits were paid to the works of Messrs. Platt Bros. & Co. Ltd., textile engineers, and of The Moston Mill Co. Ltd., ring spinners. A civic reception was accorded the visitors and the conference was held at the Municipal Technical College. The delegates were entertained to luncheon at The Union Club and the Mayor of the Borough (Alderman Elisha Bardsley, J.P.) occupied the chair and offered a warm welcome to the visitors. The Mayor was supported by the Rev. Geo. Shillito (Chairman of the Higher Education Committee), Mr. H. W. Wilkinson (Messrs. Platt Bros. & Co. Ltd.), Mr. E. M. Roberts (Federation President-elect), Mr. Norman Collinson (Past-President) and others. Mr. W. Munn Rankin, the retiring President of the Federation, was unavoidably absent. Mr. Collinson (Batley) responded and expressed the warmest thanks of the Federation for the welcome accorded the delegates, and Mr. H. Holroyd (Huddersfield) supported.

Mr. H. W. Wilkinson (Messrs. Platt Bros. & Co. Ltd.) commended the work of the textile societies generally and said they must look for advancement in our own cotton-spinning industry if machinists were to get busy again. Lancashire alone contained about one-third of the world's spindles, yet the machinery was about thirty years old on the average.

The Annual Meeting was held at the Technical College, Mr. J. W. Wolstenholme of Rochdale (Past-president) occupying the chair.

On the motion of the Chairman, seconded by Mr. J. Burgess (Ashton-under-Lync), Mr. E. M. Roberts (Bradford Textile Society) was unanimously elected President for the ensuing year.

Responding, Mr. Roberts commended the work of the retiring President, Mr. W. Munn Rankin. Owing to prevailing economic conditions many textile societies were carrying on under difficult circumstances and the problem confronting an organisation like the Federation was as to how societies not possessed of the advantages of the larger organisations could be assisted. It was highly important that the work of all local societies should continue. Important problems were cropping up in the industry and many of them could be discussed with benefit to all concerned. He was convinced that they might now look forward to better times ahead for their industry, and it was highly desirable that the textile societies should go forward in their endeavours.

The Annual Report of the Committee of Management was presented and adopted, after which the Committee was elected for the ensuing year as follows—Lancashire—C. E. Anderson (Ashton), W. P. Richmond (Nelson), G. H. Thompson (Oldham), and J. W. Wolstenholme (Rochdale). Yorkshire—N. Collinson (Batley), R. G. Eskdale (Bradford), and H. Holroyd (Huddersfield). Leicester—J. H. Lenton (Leicester). Textile Institute Representatives—A. Saville (Yorkshire Section), H. Nisbet (Lancashire Section).

The Hon. Secretary-Treasurer (Mr. J. D. Athey) and the Hon. Auditor (Mr. W. Kershaw) were re-elected.

An invitation to hold next year's Conference at Halifax was unanimously accepted, the date to be agreed upon later.

An interesting Paper on "Oldham: its Progress and Industries" was contributed by Mr. G. H. Thompson, F.T.I.

Finally, tea was served at the Union Club and a collection in favour of the Mayor of Oldham's League of Service Fund realised £4 13s. od., the Mayor gratefully acknowledging the contribution.

NOTES AND NOTICES

Annual Conference at Harrogate

There is every indication of a really satisfactory attendance of members and friends at the Annual Conference of our Institute which is to take place at Harrogate in the latter part of Whit-week—7th, 8th and 9th June, with a special extension to the 10th June, in order to provide for a visit to the laboratories of the Wool Industries Research Association at Torridon, Headingley, Leeds. The Conference proceedings will open with a Civic Reception at the Winter Gardens on the Wednesday evening, when the visitors will be received by the Mayor and Mayoress of the Borough—Alderman J. Arthur Whiteoak, J.P., and Mrs. Whiteoak. The Conference proper will begin on the Thursday morning and will be held in two rooms at the Grand Hotel. In the afternoon of the same day there will be an excursion to York and the journey will be effected by special train. On arrival at York the party will journey by motor and visit the Minster, the works of Messrs. Rowntree & Co. Ltd., and the L.N.E.R. Company's Railway Museum. In the evening, after return to Harrogate, there will be an Institute Dinner, and at this event there will be a presentation of the Institute Medal to Mr. F. W. Barwick, Chairman of the Selection Committee, whilst the Annual Mather Lecture will be contributed on this occasion by Dr. T. Oliver, of Galashiels. The Conference will be resumed on the Friday, and to all members who have notified attendance programmes are now available for dispatch. It is unfortunate that the newly-elected President of the Institute—Sir William Clare Lees—will be unable to attend at Harrogate owing to a long-standing previous engagement, but Mr. George Garnett, J.P., the immediate Past President, has kindly promised to attend.

The Institute Scholarship Holders

Mr. Alan Ratcliffe, the first scholarship holder of the Institute, is now nearing the completion of his three years' of special training and experience. In his final year he has already spent several months in the Chemnitz district of Germany, thence proceeding to Vile, Denmark, where he is now stationed at the mills of Mr. Windfeld-Hansen, a member of this Institute, who very kindly entered into arrangements whereby Mr. Ratcliffe could take up temporary occupation of an advantageous character. Excellent reports have come to hand in relation to Mr. Ratcliffe's Continental experience and service. In the case of the second holder of the scholarship of the Institute, Mr. William Graham, arrangements have been made whereby he will secure mill experience in the Lyons district of France over a period of about six months. In July he will proceed to the works of Messrs. Diederichs at St. Colombe. The reports of this scholarship holder also indicate the establishment of an excellent record during his two years of special training at the Manchester College of Technology.

Analysis of Warp-Knitted Fabric

Since the appearance of our April issue on page P67 of which an inquiry for a method of analysis of warp-knitted fabric appeared, three communications have been received at the Institute. All were sent to the inquirer himself and in two instances the matter supplied is of such interest that it is published for the information of all members.

First Communication—From H. Cook, Dunfermline—

In reply to the query in this month's issue of the *Institute Journal*, re "Analysis of Warp Knitted Fabrics," I have pleasure in giving particulars of a method which I find to work very successfully.

Warp knitted fabric may be one of two kinds—(a) Single bar fabric in which there is only one warp, and consequently one thread per needle, (b) double bar fabric in which there are two warps and two threads per needle.

The fabric consists of courses or horizontal ribs, and wales or vertical ribs.

The courses per inch vary according to the tension applied to the yarn and can easily be ascertained by means of a counting glass. The vertical ribs are regulated by the gauge of the machine, there being one rib for each needle.

The shrinkage from the grey or knitted width, to the finished width varies from 20% to 40% according to the quality of the fabric made. The usual gauges of the machines are 26-28 and 32 needles per inch. To take out the threads it is first necessary to determine which was the last course to be knitted. This is necessary because the threads can only be taken out in the reverse order to that of knitting. There is no difficulty experienced in taking out a thread from single bar fabric, as there is only one thread per needle and no interlocking threads. It is only a matter of taking the end thread and pulling it in a manner similar to taking out a weft thread from a woven fabric. With double-bar fabric more difficulty is experienced due to the interlocking formation of the loops, but with a little patience the threads may be extracted from this class of fabric also.

In double-bar fabric there are two threads per needle, and these two threads, one from each beam, form the rib. To extract the threads, the two threads forming a rib must be found and pulled together; an ordinary sewing needle is helpful in easing the threads when they are caught by the adjoining loops.

Having got out the first two threads successfully the rest can be easily removed by pulling the next two consecutive threads in turn until the required number has been reached.

These threads may now be tested in the usual way for strength, twist, etc.

On examining the threads it will be found that one thread is longer than the other, the longer one being from the top beam. By marking off a distance of say 1 in. on the fabric before pulling out the threads, the difference in length can be measured and will give the ratio of one beam to the other.

By adding the length of the two threads together and multiplying by the number of vertical ribs per inch and by the width of the fabric and by 1 yard, the total length of yarn in the 1 yard sample will be found and if the weight of the sample be known the count can be calculated.

e.g.—1 yard of art. silk fabric weighs 7 oz. On examination it was found that the length of the thread from the top beam was $7\frac{1}{2}$ inches and that of the bottom $5\frac{1}{2}$ inches with 40 vertical ribs per inch, what will be the denier of the yarn?

$$\begin{array}{rcl} \text{Length of yarn in 1 in. of 1 vertical rib} & = & 5\frac{1}{2} \text{ in.} + 7\frac{1}{2} \text{ in.} = 13 \text{ inches} \\ \text{" " " " inches in 1 yd. of 1 vertical rib} & & = 13 \times 36 \\ \text{" " " " yards in 1 yd. of 1 vertical rib} & & = \frac{13 \times 36}{36} \end{array}$$

$$\text{" " yards in 1 yd. of 54 in. fabric} = \frac{13 \times 36 \times 40 \times 54}{36}$$

Weight of sample = 7 oz.

$$\text{Length in 1 lb.} = \frac{13 \times 36 \times 40 \times 54 \times 16}{36 \times 7} = 59,428 \text{ yards}$$

and from tables - 75 denier.

Trusting I have made this sufficiently clear and that it may be of use to the Information Bureau.

(Signed) HENRY COOK

Second Communication—From T. S. Stott, Manchester—

To analyse a warp-knit fabric it should be remembered that in the majority of cases such fabrics involve the use of two bars—the bottom bar giving the face of the cloth. With the face of the cloth upwards cut the material with a razor blade into strips taking care to make each cut along the furrow between each successive rib. The cuts between each strip (or tail) should not sever the fabric at first, though if lengths of yarn are required they can be completely severed subsequently. With a mounted pin draw the end of each "tail" away from the fabric when the warp thread will be found intact.

Congress on Scientific Management

At a recent meeting, held at the offices of the Federation of British Industries in London, Sir George Beharrell presiding, unanimous decision was reached in favour of holding the Sixth International Congress on the subject of Scientific Management in this country during 1935. Mr. Frank Nasmith, the Hon. Secretary of the Institute, attended as the representative of the Council, and there was a highly representative gathering. His Royal Highness the Prince of Wales is to be invited to become Patron of the Congress, and it was agreed that three Committees be set up as early as possible to deal with—Finance, with Mr. J. R.

Freeman as Chairman; Organisation, with Dr. Armstrong, F.R.S., as Chairman; and Technical, with Sir Henry Fowler as Chairman. It was understood that it will be the province of the Finance Committee to raise the funds necessary for the conduct of the Congress.

Employment Register

In connection with the Employment Register of the Institute, there is now a fairly considerable list of members whose services are available. A special form is now provided for registration purposes which applicants are asked to fill in so that a record of qualifications and other particulars may be readily prepared and sent out to inquirers. The following announcements are recorded—

No. 102—Young Textile Engineer desires situation; 12 months' ring spinning assistant; seven years' blowing-room and carding engine fitter and erector; 18 months' woollen, worsted and waste draughtsman; three years' U.L.C.I. cotton spinning certificates; London City and Guilds A. and B. prize winner; two years' general textile technology; knowledge of German language.

No. 104—Desires position as Assistant Cotton Mill Manager or an administrative post; age 28 years; two years' training in cotton spinning; nine years' experience in cotton spinning and weaving; B.Sc.Tech.; one year at University of Paris.

Secretarial Appointment

An Associate of this Institute, Mr. Thomas Beresford Boothman, A.T.I., of Chadderton, Oldham, latterly in the employment of the Lancashire Cotton Corporation, was recently appointed Secretary of the Bolton Master Cotton Spinners' Association in succession to Mr. A. Hill, whose retirement takes place at the end of June. Mr. Boothman received his technical training at the Oldham, Leigh, and Ashton Technical Colleges, and succeeded in obtaining a number of honours. The appointment was the result of selection from upwards of one hundred applicants, and it was announced that a commencing salary of £520 per annum is attached to the post. Mr. Boothman is not yet 30 years of age and is a nephew of Mr. Henry Boothman, J.P., Secretary of the Operative Spinners' Amalgamation.

Institute Membership

At the May meeting of the Council, the following were elected to Membership of the Institute—*Ordinary*—G. H. Hotte, Massachusetts Institute of Technology, Cambridge, Mass., U.S.A. *Junior*—J. A. Bell, Wells Lodge, Hawick, Scotland (Student in Hosiery Manufacture); J. V. Davidson, 1 Ivy Bank, Kirk Lane, Yeadon, near Leeds (Woollen Designer); F. G. Holroyd, 3 The Oval, Allerton Road, Bradford, Yorks. (Analytical Chemist); W. G. Hopkinson, Alvie Terrace, Greenfield, near Oldham (Clerk); A. G. H. Rimmel, Town End Chemical Works, Bramley, Leeds (Dyeing Student); F. Taylor, 662 Hollins Road, Oldham (Cotton Spinner); W. C. Thomson, 66 Sussex Road, Southport, Lancs. (Assistant Works Manager—Knitting).

Manchester City Scholarships

The Manchester City Council is again offering a number of Scholarships tenable in the Faculty of Technology of the University of Manchester. Successful candidates are required to follow a full-time course leading to the degree of Bachelor of Technical Science in the College of Technology and Matriculation or its equivalent is an essential qualification. For students who have been engaged in industry, and who have attended part-time day or evening classes, the Scholarships are of the value of £100 per annum, while for students leaving Secondary or Central Schools the value is £60. Both classes of Scholarship are tenable for three years.

REVIEWS

Kammgarnspinnerei. By G. Fritzsche (Technologie der Textilfasern Series). Published by Verlag Von Julius Springer, Berlin, 1933. (183 pp. and index; R.M. 21.)

This book on the technique of worsted yarn manufacture is a comparison to the book on woollen spinning already published. The book is well printed, and its outstanding feature is the excellence and profuseness of the photographic illustrations and diagrams. The whole range from wool scouring to fancy yarn production is covered in the space of 180 pages, so that the treatment can hardly be described as exhaustive. Nevertheless, a great amount of essential detail has been covered and the book will serve as an excellent general test book of the worsted industry at its present stage of development. The sections on carding and combing are limited and seem to have been sacrificed in comparison with the drawing and spinning sections, which are much more extensive. Of particular interest in the earlier sections, however, are the frequency distribution curves showing the effect on fibre length of different methods of scouring, drying, oiling and setting of the cards. This is one indication of the critical way in which the book has been written and is an example of the gradually increasing application of scientific method to manufacturing problems. This attitude is evident throughout the book. In the drawing section, the intersecting gill is very well described and illustrated, and included as a standard machine showing how quickly its advantages over the ordinary gill box are being realised, especially on the Continent. It is perhaps only natural that the section on English open drawing is very brief compared with that on the Continental method. The spinning section is the most complete. There is a full account of the worsted mule and the section on spinning includes such recent developments as the raised drafting head, and mule type spindles in ring spinning. No mention is made of the combination of the England and Continental systems, known as the "Anglo-Continental," which is gradually finding favour in this country. The concluding section on methods of power supply is useful, and the author has an obvious preference for electric driving. This is a matter, however, which has caused endless discussion, and the relative advantages depend to a great extent on local circumstances. On the whole a very readable and useful book, especially to those interested in Continental drawing and spinning.

G. R. S.

The Outfitters' Salesman. By E. Ostick, M.A., L.C.P., A.T.I. Sir Isaac Pitman & Sons Ltd., London, 1933 (illustrated; pp. xiii + 157, 5s. net).

The sub-title describes this book as "A guide for retail distributors in men's and women's outfitting trades." As such, the book should be welcomed, as the author's aim is to raise the status and dignity of salesmanship in outfitting from the humdrum service of the shop automaton who merely exchanges his wares for the cash of his customers.

To accomplish this object, the author indicates the essential data as a basis on which to build up a good general knowledge of the chief features of interest relating to the articles which he sells. This includes the study of the physical characteristics of the materials of which these articles are produced, their construction and suitability for their specific purpose, and such other information as may be helpful to promote their sale and, equally important, to establish confidence in the purchaser. At the same time, while recognising the accepted principle that knowledge of goods is an important selling factor, the author also recognises that courtesy and tact are personal attributes not less essential to good salesmanship.

The book under review comprises 18 chapters and a good index, but several of the illustrations are very poor and not in keeping with the general excellence of the book. This criticism refers more especially to Figs. 1 to 7 inclusive, and Figs. 10 and 11. Figs 1 to 6 are poor line drawings of what profess to be typical examples of several of the principal types of textile fibres of commerce. These would have been much more faithfully represented by photo-micrographs of the actual fibres. The counting glasses shown in Fig. 7 would have been better photographed, while Figs. 10 and 11, showing a section through a plain loom, and a reed, respectively, are quite unworthy of a place in this book.

Apart from these little blemishes, the subject matter is treated in an efficient manner from the proverbial "A to Z," or, more literally, from head to foot, since

it includes hats and hose, and every intermediate article of clothing for men, women, and children, both for underclothing as well as for outer wear, not omitting such trifling, though important, details as the pocket handkerchief, collars and ties, and the ubiquitous umbrella.

The first chapter is introductory, and treats of the study of merchandise in general. Then follows, in chapters 2 to 6, a general technical description of the chief types of textile raw materials and their conversion into yarns and threads, a description of the mercerising of cotton, and a chapter on silk and silk goods. This concludes what are virtually the first 45 pages of general textile technology stated in simple language devoid of the terminology of the textile trade.

The remainder of the book then proceeds to describe the salient features, from the standpoints of the salesman and customer, of the various garments produced from the different varieties of textile materials, of the essential properties and peculiar characteristics of which the salesman has now acquired a general knowledge from the earlier chapters.

The book abounds in useful hints regarding the laundering and general care of the various articles described, as well as in sound dicta and advice to the aspiring salesman, while the last chapter, 18, on salesmanship, is an admirable summary of the methods adopted by the efficient salesman—of both sexes. This book can be heartily recommended as a useful and helpful textbook on the art (or is it a craft?) of good salesmanship in any branch of the clothing trade. H. N.

Farmers' Sheep and Wool. By J. Carew. Queensland, Department of Agriculture and Stock, Brisbane.

The author has set himself the difficult task of supplying information which will be useful to the experienced pastoralist as well as of service to the novice, and the farmer who contemplates sheep breeding as but one of his enterprises. Articles previously published in the *Queensland Journal of Agriculture* are reprinted in this booklet. The subjects range from a short description of sheep country in Queensland to sheep diseases and parasites; chapters are included on shearing, wool classing, conservation of fodder, etc. with a contributed section on the blow-fly. But there is little sense of proportion in the desultory treatment of the information imparted. Too frequently occur statements which reflect either over-condensed expression or insufficient evidence, while many sections fail to fulfil the promise of their headings; Chapter III on the "Selection of Breeds" is one instance of the inadequate discussion of a matter of prime importance, especially to the small farmer.

The numerous illustrations do not mitigate the disappointment of the reader.
J. E. N.

Annual Reports of the Society of Chemical Industry on the Progress of Applied Chemistry. 1932. Published by the Society. (Vol. XVII, pp. 721, price 12s. 6d.)

Though only two or possibly three of the 26 sections of this book deal directly with the textile industries, it may safely be asserted that no textile chemist who is worth his salt will miss reading many other sections, even though this has to be done at his own fireside. The sections on Mineral Oils; Intermediates and Colouring Matters, Fuel, Oils, Fats and Waxes; Resins; Indiarubber; Sugars, Starches, and Gums are, for example, well worth reading, apart from the probable acquisition of new ideas which may arise from so doing. Dr. Yarsley writes on Textiles, Fibres and Cellulose, and gives us a well-balanced summary of the year's efforts in 21 pages. Dr. H. Ainsworth Harrison writes the report on Pulp and Paper in 23 pages, and Mr. W. Harrison writes a 15-page account of Bleaching, Dyeing, Printing, and Finishing. All these are written by well-known experts in the various fields at the cost of a large amount of time and trouble, mainly for the benefit of workers in the industries. Since the inception in 1916 of the scheme to report annually on the Progress of Applied Chemistry in all its branches, these volumes have been found by the reviewer to be a considerable source of inspiration for fresh ideas and can be heartily recommended to those who do not already know their merits.
F. C. W.

PUBLICATIONS RECEIVED AND ADDED TO THE INSTITUTE LIBRARY

Report of the Thirteenth Annual General Meeting: British Cotton Industry Research Association. Published by the Association, Shirley Institute, Didsbury, Manchester.

This document contains the addresses by the Chairman of the Association, Mr. H. P. Greg, and Dr. R. H. Pickard, Director of Research.

Report of the Thirteenth Annual General Meeting: Linen Industry Research. Published by the Association, Lambeg, N. Ireland.

Addresses by the Chairman of the Association, Mr. H. L. McCready, and the Director of Research, Dr. W. H. Gibson, are recorded.

Report of the Council, 1932-33: Wool Industries Research Association. Published by the Association, Torridon, Headingley, Leeds.

This document contains the Report of the Council, together with a list of the Association's Publications and Patents.

Fifteenth Annual Report of the National Research Council: Dominion of Canada. Published by the Council, Ottawa, Canada.

Contains a review of the activities of the Council, a financial statement, and reports of laboratory divisions; summaries of the activities of Associate Committees, and of reports on assisted researches are also given.

Encyclopædia of Cotton Fabrics. By Walter Hough. Published by John Heywood Ltd., Manchester and London (84 pp. Price 3s. 6d. net.)

The fifth edition, with additions of new cloths, of this handy little work of reference.

Wool Year Book, 1933. Published by the *Textile Mercury*, Manchester (718 pp. and Index. Price 7s. 6d. net).

The twenty-fifth edition of a reference volume now well-known and extensively used in the wool textile industries.

Cotton Year Book, 1933. Published by the *Textile Mercury*, Manchester (726 pp. and Index. Price 7s. 6d. net).

This is the 28th edition of the companion volume to that referred to above and with it constitute a work of reference of real service to those engaged in the textile industries. The introductory review of the Cotton Industry for 1932 is well worth recording.

The Silk and Rayon Directory and Buyers' Guide of Great Britain, 1933. Published by John Heywood, Ltd., Manchester (450 pages. Price 21s. net).

This directory now appears for the ninth successive issue. It is well arranged and includes its information under a number of varied and useful classifications. The general index of firms is a notable feature not common enough in directories.

The Lancashire Textile Industry, 1933. Published by John Worrall Ltd., Oldham (430 pp. Price 15s. post free).

This directory claims, and we think justly, to be thoroughly reliable and up to date. A graph showing the fluctuations which have occurred in the number of cotton spinning and weaving firms in Lancashire and their equipment since 1880 is included and is a valuable addition to this volume. We still feel that to encounter a coloured page of advertisements when searching the Buyers' Guide or any other section of a directory is a hindrance rather than a help and doubt whether the advertiser is well-advised to seek such a position. On the other hand, the format which gives editorial matter on all right-hand pages and allied advertising matter on left-hand pages is definitely helpful. These directories have very much improved typographically in the last few years and their publishers are to be commended in this respect.

THE JOURNAL OF THE TEXTILE INSTITUTE

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PROCEEDINGS

ANNUAL CONFERENCE OF THE INSTITUTE

**Harrogate, Wednesday, Thursday, Friday, and Saturday
7th, 8th, 9th, and 10th June 1933**

Mayoral Reception, Wednesday, 7th June

The Conference proceedings opened on Wednesday evening, 7th June, with a reception by the Mayor and Mayoress of Harrogate (Alderman John Arthur Whiteoak, J.P., and Mrs. Whiteoak), at the Winter Gardens.

The Mayor, in offering a welcome to the members, on behalf of the town of Harrogate, said he hoped the time they spent in Harrogate would be profitable to them. He hoped that their deliberations would go some way towards assisting the trade out of the present depression. The Mayor also referred to the effect of Japanese competition on the textile industries.

Mr. George Garnett, Immediate Past President of the Institute, thanked the Mayor and Mayoress for the warm welcome extended to members of the Institute.

Conference Proceedings, Thursday, 8th June

The Conference opened on Thursday morning in two rooms, simultaneously, in the Grand Hotel, Harrogate, which was the headquarters of the Conference. The programme of papers dealt with "Finishing" and individual contributions were concerned with specific aspects of the general subject. The papers* read and discussed on the first day were as follow -

Room 1 (10.0 a.m. to 12.45 p.m.)

- (a) "Quantitative Research on the Dyeing of Viscose Yarns," by A. E. DELPH, LL.B., B.Sc. (Courtaulds Ltd.). Chairman—Mr. C. M. Whittaker.
- (b) "Some Observations on the Behaviour of Vat-dyed Cotton," by F. SCHOLEFIELD, M.Sc. (Manchester), B.Sc. (London and Leeds), F.I.C., F.T.I., and H. A. TURNER, M.Sc., A.I.C. (College of Technology, Manchester). Chairman—Mr. H. H. Bowen.
- (c) "The Absorption of Direct Dyestuffs by Cellulose," by S. M. NEALE, M.Sc. and W. A. STRINGFELLOW, B.Sc., A.I.C. (College of Technology, Manchester). Chairman—Mr. W. P. Walker.

Room 2 (10.0 a.m. to 12.45 p.m.)

- (a) "Some General Sources of Faults in Textile Materials," by Dr. L. L. LLOYD (Bradford Technical College). Chairman—Mr. E. T. Holdsworth.

*To appear in subsequent issues of the *Journal*.

- (b) "The Structure of the Wool Fibre in Relation to the Finishing Processes of the Wool Textile Industry," by Dr. J. B. SPEAKMAN, D.Sc., F.T.I. (Department of Textiles, University of Leeds). Chairman—Professor E. Midgley.
- (c) "Cloth Milling with Acids," by A. YEWDALL (Department of Textiles, University of Leeds). Chairman—Mr. Henry Binns.

Excursion and Visits, Thursday, 8th June

Conveyed by special train from Harrogate to York, members first visited York Minster, and were conducted round the building by a member of the Minster staff. From the Minster, buses conveyed members to the works of Messrs. Rowntree and Co. Ltd., where special guides were provided who took charge of small groups and explained processes and machinery seen on passing through the buildings open to inspection. Tea was taken in the Company's canteen, and a souvenir gift made to all members on leaving. The return to Harrogate was made by the same means as the outward journey. Time did not permit of a visit to the Railway Museum as had been planned originally.

Dinner at the Grand Hotel, Thursday Evening

The dinner was held at the Grand Hotel on Thursday evening, 8th June. Mr. George Garnett, J.P., Immediate Past-President, presided in the absence, owing to a prior engagement, of the President, Sir William Clare Lees.

Mr. Henry Binns, Chairman of the Council, proposed the toast of "The Guests," and expressed his pleasure at the privilege of being able to do so. There were present the Mayor and Mayoress of Harrogate, who had given members such a hearty welcome the previous evening, and on whose behalf he sincerely thanked for all that had been done for the Conference. Mr. Binns also referred to the fact that there was present as a guest of the Institute Mr. Thorp Whitaker, President of the Society of Dyers and Colourists, with which Society the Institute worked in the happiest relationship. Mr. Binns spoke in praise of the attractions and situation of Harrogate, which he said could compare favourably with Continental resorts. He referred to the new developments now being made in Harrogate, notably the sun parlour, and congratulated the Mayor and Corporation on their enterprise.

The Mayor of Harrogate, in response, stated that while listening to the proposer of the toast, he thought he might have been a member of the Harrogate Corporation, because he had sung the praises of Harrogate quite as well as he could have done himself. The members of the Corporation were very grateful to him. His Worship went on to say that the Mayoress and he had much enjoyed both the previous evening and the present occasion; they were personally grateful for the hospitality extended to them by the Institute. He hoped that those attending the Conference would enjoy their stay in Harrogate and that the event would be a success.

Over a hundred members and their friends attended the dinner, and the guests included the Mayor and Mayoress of Harrogate; Alderman and Mrs. Whiteoak; Alderman and Mrs. W. Stott; Alderman Kidson; Mr. Thorp Whitaker, President of the Society of Dyers and Colourists, and Miss Ackroyd; Mr. Arnold Frobisher, Secretary of the Wool Industries Research Association; Mr. F. J. C. Broome, Publicity Manager, Harrogate; and many of the readers of papers at the Conference.

PRESENTATION OF THE INSTITUTE MEDAL

This ceremony followed the Institute dinner and was conducted by Mr. George Garnett. He said that the Council of the Institute wished to take the opportunity of paying a tribute to the services of one of its members by the award of an Institute medal. He called upon Dr. J. C. Withers to introduce the recipient.

Dr. Withers said he had the honour to introduce *Fred Wilkinson Barwick*, Fellow of the Institute, for the award of an Institute medal.



Mr. F. W. BARWICK
Awarded the Textile Institute Medal
June, 1933

"The commercial life of the City of Manchester," said Dr. Withers, "and one may say of the British Cotton Industry, is centred in the Royal Exchange. Around the inside of the dome of the Exchange is carved a most suggestive motto, which says--

He who seeks high Heaven's
treasure

Must use no guile in weight or
measure,

and up in the heights above, one floor beyond the reach of the lifts, the Chamber of Commerce maintains a Testing House where guile receives its just rebuke. The presiding genius is our medallist, Mr. Barwick."

"Mr. Barwick received his introduction to textiles at the Bradford Technical College, and I know it must be a source of great satisfaction to Professor Barker, who is shortly retiring, to be here on this occasion.

Mr. Barwick then went to the Imperial Institute, South Kensington, the home of much pioneer work in the study of fibres. From London he moved to Belfast as Director of the Testing House there, and then in 1911 he came to Manchester to succeed one whom we may properly, and with pride, refer to as our founder, our perpetually-young first Fellow of the Institute, Mr. J. H. Lester. Mr. Barwick has now for 21 years directed the Manchester Testing House with conspicuous ability. The remarkable freedom of the commercial life of Manchester from litigation and its honourable reputation for the faithful discharge of contracts are, we venture to say, in no small measure due to the correctness and fairness of the decisions made by Mr. Barwick and his colleagues.

"But this evening, we think of him chiefly for his interest in our Institute. His membership dates back almost to the foundation. He is a most faithful member of the Council, and we rejoice that at the recent election he again received the largest number of votes. He has been Chairman of the Publications Committee, and is now wielding a most useful influence as Chairman of the Selection Committee. He is constantly striving for the reputation and dignity of the Institute, and a year or two ago expressed his sense of this dignity by presenting a beautiful jewel or badge of office to be worn by our Presidents on formal occasions, and it gives me great pleasure, Mr. President, to ask you on behalf of the Council and members of the Institute, to be good enough to make this presentation."

Mr. Barwick, after receiving the medal from the hands of Mr. Garnett, said he was extremely proud of the honour they had done him in presenting him with the medal, which he would always treasure as a memento of his association with those who had done far more for the Institute than he could ever hope to do.

"We are all keenly interested in the welfare of the Institute," continued Mr. Barwick, "and it must be a source of satisfaction to us to realise the vast progress that has been made during the past ten or twelve years. Real progress has been made in many directions, perhaps not in all the directions that we planned for;

some are for the future. But we have made marked progress in two directions, and these are with regard to the *Journal* and the development of the Diploma Scheme. The *Journal* has attained for itself a unique position. I think it would be correct to say that no other textile journal in the world covers so wide a field or covers its field so efficiently. The establishment of the various awards, which the granting of the Royal Charter made it possible for the Institute to bestow, is, I think, another evidence of progress. We have the Institute Medal with which you have honoured me to-night, the Warner Memorial Medal which is awarded for published original work in textile technology, and then we have the Honorary Fellowship, which the Council has endeavoured to constitute as the highest award that it is possible to attain in the textile industry. The names of Cross, Lowe, and Nasmith are, I think, proof that this standard has been maintained. I sometimes wish that the Institute had been in existence 100 or 150 years ago, for then, on the list of Honorary Fellows, we should have had names like Hargreaves, Arkwright, Crompton, Cartwright, Lister, Holden, and others. I should like to think of those names as a guide to fixing a standard for the Honorary Fellowship. I feel jealous of that award, and I think we ought to have such names in mind when we are considering future recipients. With regard to the Fellowships and Associateships of the Institute, these are increasingly sought after by young men coming into the industry, and who show that they are willing to meet the requirements which the Institute has set up for these awards. The standards are necessarily high, If these awards were to be had for the asking, they would be of no value. But candidates who are coming forward for the Associateship have already attained a high standard in their own branches of the industry. In order to qualify they are willing to take additional courses in General Textile Technology so as to amplify the knowledge that they have already gained in their own section of the industry. Our Examination in General Textile Technology has recently had to be held in seven centres, two in England, two in India, two in South America, and one in Australia, and if proof were needed of the success of the Institute Diploma Scheme, I think that imposing list of examination centres would provide that

proof. I will conclude by thanking you most sincerely for the great honour you have done me, which I fear I have not done very much to gain."

Annual Mather Lecture, Thursday, 8th June

This lecture, instituted in honour of the late Sir William Mather, a Past-President of the Institute, was delivered after the medal award ceremony described above.

In asking Dr. T. Oliver, of Galashiels, to deliver this lecture, Mr. Garnett pointed out that he succeeded a long line of eminent men who had, in previous years, honoured the Institute by contributing the Annual Mather Lecture. These lectures had done much for the stimulation of our great textile industry, and that now to be delivered would not fall short in that respect. It was noteworthy that Dr. Oliver had chosen the "human element" in industry. Dr. Oliver then delivered the lecture as it appears hereafter—



DR. T. OLIVER
Delivered Annual "Mather" Lecture
June, 1933

THE HUMAN ELEMENT IN THE TEXTILE INDUSTRIES

By T. OLIVER, D.Sc. (Edin.); B.Sc. (Lond.)

In essaying to address this audience I am placed at a disadvantage because on previous occasions the Mather lecturer has been of outstanding eminence in some branch of learning not directly connected with the textile industries. On this occasion, your Council has considered fitting to honour one who has been so immersed in a mass of textile problems for nearly half-a-century that he may well be pardoned if he should feel somewhat nonplussed. Obviously I cannot attempt to imitate my predecessors, and I have no guidance from previous examples how other textile technologists would deal with such a problem.

With some show of alliteration I state the main essential factors in the textile industries to be—(1) Materials, (2) Mechanism, (3) Men. I have had only a specialised knowledge of materials and mechanism and anything I could tell you under these headings would not be of sufficient general interest. Therefore, I have selected the third factor as the subject of the lecture, because I have had a life-long contact with the subject.

In the first place, I may say that the textile industry requires more uniform skill than any other large industry does, and hence the human element triumphs over the purely mechanical to a maximum degree. In iron and steel manufacture, engineering, ship-building and house-building there are many workers who require only physical strength. But in the textile industry there is really no unskilled work. From fibre to fabric, success depends on rapid and exact workmanship. Moreover, in normal times, textile raw materials are usually expensive and hence much depreciation of stock may occur through defective work. In many trades, continuity of process has been perfected to such a marvellous degree, that it is asserted that raw material may be fed in at one end of an apparatus, and a finished product will appear at the other end without human intervention at all. But there are important gaps in the textile industry which have not been bridged by invention and may never be, *e.g.*, it is quite within reason that textile material fed into a machine should appear at the other end as twisted thread on a bobbin. But an important hiatus occurs between spinning and warping. A second occurs between warping and weaving and a third between weaving and finishing. It may be possible to make the finishing of certain cloths continuous, but for the better class of woollen cloths in which my life-work has been cast, quality of workmanship would be sacrificed for quantity of production by adopting that process.

In studying the human element in manufacturing, for convenience we may divide the subject into two categories, relative to (a) the work of the supervisor and (b) the work of the supervised. Due to the great changes in process of manufacture, there has been even more rapid change in the problems presented by modern textile business. The typical manufacturer in the 19th century started with two or three workers and without clerks. He gave out the material to the workers, he entered the orders, sent out the accounts, paid the workers personally. He knew his costs without formal records, he checked slothfulness and waste in a way unattainable by the most efficient modern firm. As the mill increased, his original workers became foremen. Discipline and good work were maintained. Good output went hand-in-hand with a contented community. The eyes of the manufacturer were everywhere, his vision seemed to be uncanny, but its range developed with his experience. His stocks were always in balance, his delivery promises were reliable. When a foreman was ill, the manufacturer did his work. Indeed no job was beneath his dignity as he realised that his function was to help wherever he was needed. There was no time lost in grumbling about inefficient management, nor wasted in intrigue, nor in speculating about possible appointments, nor in combining to prevent unfair actions, nor in seeking to circumvent orders, because everything was clear and above board.

Excess organisation is a great drawback in modern industry. A chart shows the delegation of authority, and it resembles a genealogy tree. Every man has a title and his duties are strictly defined. If a worker wants to communicate with the general manager, his message has to go through certain channels. By the time it reaches the head the suggestion has been killed by criticism and possibly its applicability may have passed. Much useless correspondence often takes place between departments. The business should be planned to eliminate unnecessary conference. The main object should be to get the work done well and quickly.

Modern manufacturing has become very expensive through having attached to itself too many non-producers, vested with titles which are frequently too big for the individuals to carry. They are often more obsessed with the weight to be attached to their opinion than with the need to get the work done regardless of reputation. When responsibility is divided into many parts it is often difficult to find who is responsible. Every worker should realise that he or she is responsible for the progress of the whole mill. Advancement should depend upon work and not upon favour. Where the latter factor predominates, there are many eye servants who, failing to get credit, reckon that they might have done the work ill as well. So work becomes the secondary and recognition the primary consideration.

Where routine is the controlling force, staff advances are made by seniority, with the result that inept men are put into prominent positions which they cannot fill satisfactorily. Hence it is better that there should not be many "positions" and that every worker should be paid according to the value of work done. This will eliminate heart-burning as to who is highest in the business. When a firm and its workers conclude that they are the last word in manufacturing it is a sure sign of retrogression. A safe axiom is that no work is being done as well as it might be done. Hence the management should be open to suggestion which should not be ridiculed no matter from whence it comes because it may contain the elements of improved process. Fifty years ago a Scottish manufacturer told a would-be process improver in the dialect "Oo' pay you for working, no' for thinking." In doing so he was unconsciously destroying the finest asset in his business.

The inventor's enthusiasm is frequently reduced by the information that his suggestion has been often tried before and failed. To the enterprising man, records of failure are often as helpful as records of success, but to dwell too much on failure will tend to produce a pessimist. Some one has said that the pessimist sees a difficulty in every opportunity, but the optimist sees an opportunity in every difficulty. So that merely being occupied with failure may lead us to do nothing, because everything would appear to have been already attempted and to have ended in failure. The management should be alert to see that youths are trained for more than one operation, so that when restlessness, disease, or death deprives the firm of a worker's services, his or her place can be efficiently filled from within the works.

Manufacturers are apt to think that their workers are less efficient than themselves. If a worker is not doing well, it is generally the fault of the management. On investigation it will frequently be found that no one has taught him a better way of doing the work. The management should see that the oversight is of right character. A foreman may nominally have charge, and yet not hold himself responsible for efficient training. Some have no initiative and occasionally if they have, the manager may ask them who gave them permission to act. Some are averse to changes. Such have a great reverence for the past. But all progress has been achieved by effort and the greater and more intelligent the effort, the greater the result.

Another reason why defective workmanship is more chargeable to the management than the workers is that it is unreasonable to expect a person who has no

pecuniary interest in a business further than wage-earning should trouble more about it than one who has a share in the ownership. When a new worker is engaged he or she should be carefully taught the duties by someone who knows them thoroughly. In some instances, the poorest and slowest operators are set to teach the new hands because their services will be least missed. The practice may entail less expense, but reacts unfavourably in the long run. An instructor should not only be expert but also patient. The loss through labour restlessness is not sufficiently realised. There is much waste of material and output by always working with beginners. An economy in wages may result in a much greater loss in the cost of the finished product due to imperfections.

A new worker should be shown other departments in a mill to get ideas of their inter-relation. For example, if the yarn-makers and the weavers realised the great cost of mending and clean picking in the woollen trade, more care would be taken in their work. Personal interest on the part of the manager will always pay. He should be ready to encourage even when the work is not first-class. The teacher-operator should be warned about defects, and greater care taken that the learner should understand the process more perfectly. Such procedure would eliminate much misunderstanding and illwill.

When a youth reaches 18 years of age he may be discharged because his wage automatically becomes too high for the duty performed. It is always bad business to act meanly towards a worker who is leaving, because the action is likely to give a bad advertisement to the mill. It may be provoking when a firm keeps a worker throughout a slack period and as soon as trade improves he goes elsewhere. But it is bad policy to show any resentment. After a firm gets ill reputation no amount of good treatment will eradicate it. Long ago a Scots manufacturer earned the soubriquet "Sack him" and his mill was viewed as the sink of employment, yet his bark was much worse than his bite. He was really not so much worse than his contemporaries. As a newcomer in his mill, I was startled one morning by the old gentleman bursting into the room and exclaiming "It's funny how ye're aye busy when Aw come in." Having been trained in a mill where nothing was left till to-morrow which should be done to-day, I sought to get the overdue work cleared up. My employer seemed a little perplexed. But another worker admonished me not to repeat the process, because the manufacturer was thinking that I had nothing to do. He was always pleased when he saw his workers with plenty of work in front of them! The manager may have reason to suspect his workers, but he should never give them the idea that he does, but rather by friendly manner and word he should foster better methods and conduct.

Managers should investigate the wage bill, so as to know what each piece-worker costs to be trained, and hence the cost of discharging a worker will also be known. Learners should be encouraged to learn rapidly and well by being given a wage incentive of, say half the difference between piece wage and time wage as a bonus. If the learner appreciates that the manager has an interest in him or her, the result will be greater satisfaction and more desire to remain with the firm. This process starts with the management. It is unreasonable to expect that the workers will rise to a higher level than the management.

Mill-owners should take a broad outlook of their functions. If a factory is started in a town with the express purpose of getting all that is possible out of the workers, and giving as little as possible in return, the community acquires the same spirit and retaliates by encouraging organisation to force higher wages. Conditions arise promoting waste, greed, suspicion, discontent, labour change and ultimately poor product and low wages. On the other hand, when the mill-owner puts service to the community first, aims at finding work for the people, pays the best wages admissible, he creates a feeling of common interest and together they produce better results, a profitable organisation and a happy and contented industrial community in normal times.

Manufacturers should have a scientific outlook so as to secure an intelligent class of workers, because there is no greater industrial handicap than ignorance. The managers must be trained to analyse problems, assess ability, devise quicker methods and more accurate working so that better wages may be earned, because it is useless to lead young people into a trade which normally cannot afford a reasonable livelihood. If a trade can only afford a labourer's wage, it must be content with a labourer's skill.

Above all things, the manager should know the business. He must be decisive, punctual, tactful and patient. If nervous, moody, or talkative, he will be a failure. Some part of his leisure should be occupied with study, so that his mind may be enlarged. The busy man can always find time, the indolent man is always hard-pushed. Initiative arises from constructive thinking and courage. In discovering America, Columbus had initiative born of constructive thought and courage. All progress in the affairs of man has arisen from controlled thinking. The mind must therefore be properly nourished. Sympathy is also a great element in the formation of a manager. He must see that his deputies act fairly. In the 19th century, the common qualification of a foreman was ability to swear loudly and bully the workers, but that method is now out-of-date.

Similar remarks will also hold as to the qualifications of foremen. Their duties comprise maintaining discipline, arranging work, keeping records, making reports, training workers and superintending alterations. Foremen must be skilled so that they know when work is well done. Reliability is important, because work expresses character. A dishonest man cannot be an honest worker. Punctuality indicates discipline. Consistency is more important than mere strictness. Tact is ability to secure co-operation in establishing a team spirit. Loyalty is also important. If a firm is the channel of supply of a man's livelihood then let him work well, think well, speak well of it to the best of his ability. It is a fine spirit which prompts the worker to describe the mill as "ours" and to insert himself in the firm as "we." Willing workers always give better service than pressed labour.

As to the requirements of labour supply, textile workers should commence work as soon as they leave school. At the age of 14 years, they are keen to learn, and their nimble fingers acquire speed readily. Recently, a school-master said that employers seldom asked about certificates, but only if the applicant were strong, willing and reliable. After all, that is an admirable summary of the qualities required in every textile aspirant. Learners should be strong enough to stand all day at work. Good eyesight is also a necessary asset. The colour-blind should be stopped from proceeding along many textile avenues. We have discovered dyers, yarn-foremen, and designers who were in a measure colour-blind with disastrous results to the business in which they were engaged.

There are different kinds of workers—(1) The ambitious, who are of two sub-varieties—(a) those who want a royal road to the top and usually fall out early in the race, (b) the patient workers who will not miss the minute details of the task, who are content to spend long time in acquiring knowledge of every department of their business. Such will not only achieve success, but will deserve it. There is no greater fallacy than attributing success to luck. The so-called lucky fellow is really unfortunate, because he usually fails to carry prosperity when it comes his way. There are many heroes in adversity, but few heroes in prosperity. (2) The phlegmatic who prefer to learn one job and acquire as much efficiency as will earn the average wage. We should not decry such an outlook because although the poet may not become eloquent by the study of their cases, they form the bulk of the personnel of any industry. Most people seek to avoid responsibility. After all, genius seldom exists through successive generations. It is said that the "clogs to clogs" cycle only covers three generations on the

average. The first earns the money, the second spends it, and the third returns to the labouring class again. After possibly the lapse of several generations, once more the lamp of genius may burn brightly. (3) The necessitous who have had to sacrifice prospects for exigencies of relationship. They must work hard to earn sufficient to maintain dependents. They may have high ambition and the routine may be drudgery, but strong will and perseverance conquer the desire to run away from the pressure of the work. Such "village Hampdens" are real heroes in the industrial struggle.

A contented body of workers is necessary in the production of good cloth. An important element of contentment is good health, and so welfare work should form part of every factory organisation. It will pay all the time. In case of illness, a personal letter expressing sympathy and wishing a speedy recovery establishes an unbreakable bond. Some mill corporations are said to have become so large as to have lost all soul. If true, then the sooner these corporations are broken up the better it will be for the industry. Modern industry is too much sub-divided. Workers should be given experience on a wider variety of work.

It is often asked "What should a boy know on entering the textile industry?" It is not so much what is known but how it is known that is important! The literal meaning of "education" is to "draw out." The chief function of education is to draw out and develop latent faculties. Much of the instruction given in schools and colleges gives information but scarcely any education, as it only tends to hinder mental development by clogging the mind with dead matter. Where paths of least resistance are followed, the continuous description deadens the minds of the listeners. Therefore, a dead system of technical instruction should be eschewed, however much it may appear to bear on the routine of the business. But provided the studies are not too narrow in outlook, the closer they are related to the work, the more active the interest of the student is likely to be. Every study should exercise perception and reflection. These are stimulated in youth and should develop as time goes on. They will gradually form a fund of common sense which solves many industrial problems better than mere academic training will do. The classics and geometry have been praised as unrivalled subjects for mind-training, but I assert that the textile industries present countless problems which are equally well adapted to improve the intellectual faculty.

From the earliest times, education aimed at passing on the experience of the preceding generation. There was gradually developed a direct relation between the trade and its preliminary training. The Renaissance introduced the classical idea into education and fostered contempt for manual labour. But since the community essentially requires service, the majority of people will have to undertake some form of manual work. Hence education should inculcate a desire to work, else the community will deteriorate.

I fear that my ideas will not find favour in orthodox educational circles and I do not wish to say all I think on the matter in case it may be thought that I am seeking to detract from the impressions on "liberal education" conveyed last year by my illustrious predecessor, Sir Michael Sadler.

But I may say that Education has tended to become too pedantic and in consequence distrust has arisen between men interested in education and men interested in industry. The former condemn the latter for the materialistic purpose which they would impose on education, while the latter condemn the former, averring that current education is too academic and divorced from actual living conditions.

There is a prevalent idea that education should relieve its disciples from manual labour. This has been strengthened by the evolution of staff appointments mainly dealing with clerical duties. Much of modern industrial book-keeping

may reveal interesting facts, but does not contribute to better product. But manufacturers are largely to blame in setting a premium on clerical work by taking their managers from the office rather than from the machine. Recently a boy was offered a throstle piecership. He declined as he wanted a white-collar job in order to get on. So that the idea is deeply engrafted in the human mind. There is nothing menial in being a factory worker and indeed as industrialists insist on obedience and good conduct they are an important factor in evolving useful citizens. Very few workers have criminal tendencies. But idle hands are proverbially liable to nefarious practices.

It is distinctly unfortunate that much of the present day educational procedure is developing a class of young people who do not wish to work in factories or indeed to work anywhere at all. That result is even more remarkable in America than in this country. During my long tour in Canada and U.S.A. in 1931 I had abundant opportunity to verify the contention. Whenever a man gets above the dead level of bare subsistence he becomes obsessed with the vague idea that his family should have an easier time than he has had. He fails to see that the hard process through which he has passed has been an essential factor in any success he may have achieved. So wholesale waste of human element is in steady process through misconception of educational ideals.

Moreover, education is valueless if it does not fill people with the "milk of human kindness." Many of the "liberally educated" young people, notably in U.S.A., are really ignorant, selfish, and arrogant, since trained to believe that they are the "heirs of all the ages." They use abundant slang which shows a lack of vocabulary and appreciation of the value of words. Such people are not really clever but merely wish to gain that reputation.

As a man who has the privilege of taking a retrospect on a strenuous life, I may say that I would not care to have had it less strenuous. Forty-nine years ago I left an elementary school at 13 years of age and I have never gained a "leaving certificate." I seem to have been at school ever since! I was 12½ years in woollen mills, hard-worked and grossly underpaid (average wage 15s. 4d.) per week). For 10 years I attended evening classes, studying all sorts of subjects in a promiscuous way. No technological syllabus would suggest that Pitman's shorthand should be the first year subject. Yet I found that art one of the most useful tools in my equipment in subsequent years. No Board of studies would allow a student to take up Human Physiology as his first science. Yet I found that initial subject to be the most powerful stimulant possible to a broad study of science. I became so overcome with the extent of my ignorance that I was led to read as many books on as many branches of science as the local public library afforded, and to do as many experiments as home-made apparatus would admit. I made an electrophorus from a soap tin lid and a vulcanite knitting pin fixed with sealing wax; a burette with a piece of glass tubing, strip of foolscap ruled paper as scale and rubber tube with hair-pin pinch; a hydrogen generator from a Bovril bottle; a "fearfully made" galvanometer and many similar pieces of apparatus. With such I was able to make experiments quite beyond the range of evening students in a small town even after 40-45 years of progress from those primitive times. Comparing the small burgh evening classes of 1888/1893 with those of 1933, I often think we have been making progress like the Mexican bird which is reported to be able to fly backwards. Recently I have been assessing the textile mathematics and mechanics examination results of evening technical schools. Although the best work is very good indeed, the bulk is stereotyped. If the examiner sets an unusual question the examinees are lost, and the teachers raise a storm of protest that ends in the eclipse of the assessor's sun!

Thus I am not greatly enamoured with the utility of syllabus-making. The results resemble the record of the "valley of dry bones" in Holy Writ where the prophet was nonplussed with the idea that the bones could possibly live, but

when breath came into them they lived in perfect assimilation and articulation. I repeat that it is not what we study, but how we study that constitutes a liberal education! If present-day schemes can communicate that burning desire to know more, which is the ultimate object of every teacher worthy of his salt, then they will be well justified. Meanwhile we shall "wait and see!"

Vote of Thanks to Mr. George Garnett

Mr. F. Nasmith, Hon. Secretary, said he was sure members would wish, through him, to convey their grateful thanks to the Immediate Past-President for presiding over this Conference. Mr. Garnett had told them that the President—Sir William Clare Lees—was connected with the International Chambers of Commerce and that important prior engagements prevented him from coming to Harrogate. If Mr. Garnett had not stepped into the breach, they would have been leaderless. As they had heard the previous night, he was a most excellent leader. His past work was not merely represented by his last two years of Presidency, but for years George Garnett had been a good friend to the Institute. It was such men who had made the Institute what it was to-day. Without putting any resolution, he knew they would join with him in thanking Mr. Garnett for the work he had done.

Mr. Garnett in reply thanked those present for the way in which they had received Mr. Nasmith's proposal. It had always been a great pleasure to him to be associated with the Textile Institute. The organisation of the Institute had been largely brought about by the strenuous efforts and contributions of voluntary workers during the past 22 years. It might also be noted that their only administrative staff was Mr. Athey, Mr. Robinson, and five lady clerks. He thought all could appreciate the effect of the work being done at a very minimum of expense and overheads. He had said on more than one occasion, and he repeated it with great pleasure, that had it not been for voluntary work of the highest quality, which was continually given to the Institute, they could not have been where they were. He made bold to say that the time was not far distant when more and more of the men who were qualifying for the Diplomas of the Institute would occupy pivotal positions and it would be to these men they would have to look as the new textile leaders. To-day they were bound by the economic conditions of the times. They would have to wait until these conditions became more satisfactory and, in his view, they could only be dealt with through international media; and though the return to safe progressive lines might be near, or it might be distant, he thought we should rise stronger and wiser from the gruelling we had had since 1929. At the present time, the Institute was playing a splendid part in securing the highest type of qualification for industry. He was delighted with the atmosphere of the Institute, which stood for progress on the right lines.

Conference resumed on Friday, 9th June

The presentation of papers was continued on the Friday morning in two rooms at the Grand Hotel and the following is a list of papers introduced and discussed—

Room 1 (10.0 a.m. to 12.45 p.m.)

- (a) "The Performance of Two New Finishing Machines on Linen," by E. BUTTERWORTH, M.Sc.Tech., F.Inst.P., F.T.I. (Frazer & Houghton Ltd.). Chairman—Mr. J. W. McMyn.
- (b) "The Scouring of Linen," by E. BUTTERWORTH and H. A. ELKIN, B.A., M.Sc., A.I.C. (Gourock Ropework Co. Ltd.). Chairman—Mr. William Black.
- (c) "Fulling and Milling Machinery," by E. KILBURN SCOTT, M.I.E.E., A.M.Inst.C.E. (London). Chairman—Mr. Frank Nasmith.

Room 2 (10.0 a.m. to 12.45 p.m.)

- (a) "Some Observations on Ageing Problems," by H. B. BRIGGS, M.Sc., A.I.C. (Imperial Chemical Industries Ltd.). Chairman—Professor A. F. Barker.
- (b) "Some Defects in Finished Fabrics," by Dr. PERCY BEAN, Ph.D., M.Sc.Tech., A.M.C.T. (Manchester). Chairman—Mr. G. B. Slater.
- (c) "The Hydrogen-Peroxide Bleaching of Wool, Cotton, and Silk," by I. E. WEBER, B.Sc. (London) (B. Laporte Ltd.). Chairman—Mr. Ellis Clayton.

After lunch two further papers were presented and a demonstration given of a new photometer—

Room 1 (2.0 p.m. to 4.0 p.m.)

- (a) "Recent Developments in Textile Finishing," by L. G. LAWRIE, A.I.C. (Imperial Chemical Industries Ltd.). Chairman—Dr. F. C. Wood.
- (b) "Finishing Machinery in its Modern Form," by W. J. NORTON, B.A. (Cantab.), A.M.I.C.E. (Sir James Farmer Norton Ltd.). Chairman—Mr. A. Lomax.
- (c) Demonstration—"A New Photometer and its Application in the Textile Industry," by Dr. R. GUELKE.

Tea was taken in the Hotel dining-room by invitation of the Council of the Institute.

Visit to Wool Industries Research Association, Leeds, Saturday, 10th June

The concluding event of the Conference was a visit of inspection to the laboratories of the Wool Industries Research Association at "Torridon," Headingley Lane, Leeds. This arrangement, made by the kind invitation of the Council of the Association, formed a fitting termination to an interesting and valuable Conference. Those members staying over the Friday night in Harrogate were conveyed to Leeds direct to the laboratories, where they were received by the Secretary of the Association, Mr. Arnold Probisher. Two hours were spent in the various departments in which demonstrations and exhibitions had been prepared. These were explained by members of the staff of the Association and proved of the greatest interest. Many of the visitors obviously would have welcomed a longer visit.

Scottish Section

Meeting at Inchinnan, Wednesday, 31st May 1933.

By courtesy of Messrs. India Tyre and Rubber Co. (Great Britain) Ltd., members of the Scottish Section visited the works at Inchinnan, Renfrewshire, on 31st May. The party, which was representative of all districts in the Section, assembled at the works in the late afternoon, and were received by Mr. R. M. Davies on behalf of the Publicity Manager. The visitors were provided with a comprehensive account of the activities in the factory from receipt of crude rubber to production of finished tyres and tubes, and were conducted in parties throughout the works by guides who explained the various processes. Members were impressed by the amount of actual hand labour employed in the works and with the excellent lay-out of the plant and the conveyor systems.

At the close of the tour, the party was entertained to tea by Mr. D. D. McLachlan, Publicity Manager, when there was a short discussion of various questions which had been mentioned during the course of the tour. Altogether, a very interesting and instructive afternoon was spent in the works, and members are indebted to the Company for affording this privilege.

NOTES AND NOTICES

Conference at Harrogate

The Annual Conference of our Institute held at Harrogate in the latter part of Whit-week (7th to 10th June), proved an interesting and successful fixture. There was an attendance of over 100 members and friends. The experience of securing the contribution of a series of papers on one general subject proved further justification of this policy, which was initiated in connection with the conference at Leamington in 1932. At Harrogate, the subject dealt with was that of "Problems of Finishing," whereas in the previous year various aspects of the subject of "Textile Testing" were dealt with. From the point of view of the provision of comprehensive contributions to the literature of the subjects selected, the records of the conferences organised on the plan in question are becoming regarded as of definitely substantial value, a condition which is indicated by the subsequent demands for reprints of the Papers. There appears to be little doubt but that the policy will continue to be pursued at any rate in immediate future years. Already it has been pointed out that the two big subjects of problems in spinning and weaving might receive special consideration in the near future. At Harrogate the Mayor and Mayoress (Ald. J. A. Whiteoak, J.P., and Mrs. Whitcoak) held a reception of the conference visitors and subsequently were good enough to attend the dinner of the Institute. It was unfortunate that, owing to prior engagement, the President of the Institute, Sir William Clare Lees, was unable to attend. Mr. George Garnett, the immediate Past-President, however, very kindly resumed presidential duties and was warmly thanked for his excellent services. Although the Conference programme was somewhat crowded, enthusiasm was remarkably well maintained throughout the proceedings, and it was a great convenience that the whole of the Institute meetings could be conducted within the Grand Hotel—the headquarters for the event.

Institute Employment Register

The following announcements are taken from entries in our Register of Members whose services are on offer. Employers may obtain full particulars on application.

No. 100—Asst. Manager or Asst. Sales Manager desires similar position. B.Sc.Tech., A.T.I., A.M.C.T., and F.R.G.S.; three years' experience of mill administration, spinning, and manufacturing. Experience also as apprentice engineer.

No. 101—Asst. Designer and Weaver desires position as Asst. Mill Manager or Preparation Manager. City and G. Full Tech. Cert. in Cotton Spinning; three years' day-course cert. in Cotton Manufacture, Blackburn Technical College.

No. 103—Producer-buyer for well-known firm of Manchester merchants desires change. A.T.I. and A.M.C.T. Fully conversant with all classes of white, dyed, and coloured woven cotton and rayon goods for home, colonial, and European markets; special knowledge of Scandinavian trade.

No. 105—Loom-overlooker desires similar position or Asst. Weaving Managership. City and G. Full Tech. Cert. in Plain and Fancy Cotton Weaving; 11 years as weaver and asst. overlooker and five years as loom overlooker; also five years as practical weaving instructor.

Attention is drawn to the fact that an advertisement appears on page iv of this issue announcing a vacancy for an assistant spinning-mill manager.

Textile Institute Scholarships

At a meeting of the Scholarships Committee of the Institute, held on the 16th June, reports of the Institute Scholarship-holders were presented and approved. The first holder, Mr. Alan Ratcliffe, has now reached the concluding stage of his three years of special training and experience. At present occupied at the textile works of Mr. Windfeld-Hansen, at Veile, Denmark, he returns to this country about the middle of July and will be open for engagement of his services in a suitable capacity. He has had a brilliant career as scholarship-holder and seeks an administrative position of responsibility. The Secretary of the Institute would be pleased to supply full particulars of Mr. Ratcliffe's attainments and experience. Twenty-five years of age, he has had seven years of mill experience, two years of university training in textiles and business administration (passing all terminal examinations with excellent marks), followed by one year of industrial experience abroad. With regard to the second scholarship-holder, Mr. Wm. Graham, who is entering upon the third year of his scholarship, arrangements have been effected whereby he will proceed during July to the works of Messrs. Diederich at Ste. Colomb, France, for a period of six months. It was reported to the Scholarships Committee that, owing to the reduced interest now accruing from the invested Scholarship Fund, the question of announcement of the next Institute Scholarship required careful consideration. It was agreed to recommend that the matter be deferred until 1935. Meantime, it was decided to consider appropriate steps with a view to augmentation of the Fund.

British Industrial Art

In connection with the Exhibition of British Industrial Art, from 20th June to 12th July, at the Dorland Hall, Regent Street, London, particulars supplied show that the walls of the entrance hall are lined with material typical of those used in the modern home, the furnishing textiles employed consisting of cotton, wool, linen, silk, and rayon. In regard to the exhibits of textiles, the first gallery of fabrics is dominated by an exhibit of Wilton rugs and carpets designed by Marion Dorn, whilst the collection includes quilts, tweeds, and other cloths. A series of rooms provide demonstrations of the effective employment of textile fabrics in furnishing and decorating.

REVIEWS

The Karakul Sheep (*Das Karakulschaf und seine Zucht*). By von Dr. Phil. G. Frölich, 2. Aufl. Published by F. C. Mayer, München, 1931 (price RM. 10).

The author of this book, Dr. G. Frölich, is Director of the well-known Institute for Animal Husbandry of the University of Halle, where for many years special attention has been paid to the study of the introduced Karakul sheep, with the assistance of Dr. W. Spöttel and Dr. E. Tänzer. The account takes into consideration practically everything of farming and scientific interest which has been written on the Karakul, including the extensive researches of Dr. L. Adametz, Vienna. Chapters are devoted to the origin and geographical distribution of the breed, its bodily characteristics and fleece, the various farming methods pursued, as well as the breeding and treatment of diseases of the sheep, while the pelt of the lamb receives the special attention it demands.

The Karakul is a pelt-yielding sheep of peculiar interest. It originated in early times in the dry, sandy plains of Central Asia, a wide area with Bokhara as a centre and embracing parts of Turkestan, Southern Russia, Persia, Arabia, and Caucasia, and having a climate marked by extremes of cold and heat, and environmental conditions generally calling for a hardy constitution. Within recent times it has been introduced into various countries of Europe, particularly into Germany, as well as several parts of North America and South West Africa, where conditions are very favourable. Within the area of origin occur numerous other breeds of sheep, more or less allied to the Karakul, but of doubtful genetic origin.

as a result of the free intermingling which takes place. They are roughly divided into the broad-tailed sheep and the fat-rumped sheep, the fatty accumulations serving as so much reserve food. In the former masses of fat occur over the upper part of the tail, while in the latter large pads are deposited upon the rump and adjoining regions; as the present writer has shown, the broad tail is a phylogenetic stage of the fat-rumped. The Karakul belongs to the broad-tailed group, and the lower part of the tail has the peculiarity of twisting to one side. The fat-rumped black-headed Persian, a primitively-coated sheep from Hedjaz and Somali, has a similar tendency to twist, but curiously enough, the median symmetry of the tail tip is deemed a Stud Book requirement among the many flocks of this breed in South Africa.

In size the adult Karakul is somewhat larger than most British breeds and the lambs are completely black at birth. The ram generally carries short horns while the ewes are hornless; the head is long and somewhat narrow, and the nose arching or Roman; the ears are long and strongly pendant, and the movements free and active. The adult fleece is long and uneven at the surface, consisting of two main types of fibres; long, coarse, hairy fibres extending throughout the coat with finer, shorter, mostly woolly fibres below; cotting takes place towards the end of winter. Though black at birth, the coat begins to turn grey at about six months. In general appearance the adult fleece is not unlike that of many of the British Mountain breeds, particularly the Blackface, and has no great value.

The chief value of the Karakul is found in the covering of the new-born lamb, for it is this which provides the fur so much prized and appearing under the various names of Karakul, Persian, or Astrakhan. If left on the lamb, however, the desirable characteristics of the fur are retained for only a few days after birth, hence the necessity for sacrificing the lamb and removing and preserving the pelt. At birth, the short, black, highly-lustrous fibres are arranged in closed, horizontal "pipes" of varying length, breadth, and compactness, produced by the folding over of the fibres and the inturning of their free end. After birth the fibres grow rapidly in length and in two or three days become loose and more upright, at the same time losing their tubular compact regularity of arrangement. With this change the distinctive characters of the Karakul fur disappear. The rate at which the change takes place varies in different lambs; hence some need to be sacrificed the first day after birth while others may be kept alive for two or three days without much loss of curl, the skin growing in size and value all the time. After removal the skins are preserved either by drying and salting or by immersion in different preserving solutions. The natural blackness is retained in some instances, while in others it is intensified and rendered more uniform by dyeing.

The quality of Karakul pelts varies greatly; no two are alike, showing a lack of purity in breeding. The desirable characters of a high-grade Karakul fur may be summarised as follows. The pipes may be small, medium or large, but must be tight and compact, uniform and regular in arrangement, and distributed according to some more or less defined pattern. The hair or wool must have fineness and softness, the feel not coarse or harsh, and the colour jet black with a high lustre.

The pipes which are so unique a feature of the Karakul lamb can be shown to correspond with the well-known curly tufts of the birth coat of British breeds of sheep, but in these the tufts are usually small and spiral and stand erect, not horizontal. The birth tufts of the Blackface and Angora approach the Karakul type somewhat, but even here the loose open spiral tends to be upright, overturning only slightly. In the Karakul, as Frölich shows by a series of figures, the lower part of the birth coat is straight, but the tip turns over and inwards instead of upwards. With birth the curl tends to straighten and the whole tube opens out, and it is to forestall this that the lamb is sacrificed.

In breeding the Karakul coat is mostly dominant. Crossing pure bred rams and other breeds usually results in the black, piped, highly-lustrous coat of the Karakul. Flocks can be readily improved in quality by selective breeding. In Scotland an interesting experiment was carried out in 1913 by Professor R. Wallace, University of Edinburgh, with an imported Karakul ram. The ram was mated with 37 selected pure bred ewes from several British breeds. Forty lambs were obtained all without exception black and curly, the curls differing in degree

of tightness. The lambs showed pronounced Karakul characteristics, including drooping ears and a slight fatty enlargement near the base of a long tail.

The author may well be congratulated upon the production of a work, useful to the student and farmer alike, and well illustrated. One may point to it as a model of what it is hoped may some time be attempted by the Breeders' Associations of some of our British breeds of sheep.

J. E. D.

PUBLICATIONS RECEIVED AND ADDED TO THE INSTITUTE LIBRARY

"My Weaving Frame." By Walter Taylor. Oxford University Press, London. (8 pp. and cover. Price 1s.)

A pamphlet for those whose interests lie in the direction of hand-weaving. This illustrates the craft in its most simple form.

Rules for Arbitration Relating to Transactions in Wools and their Manufactured Goods. Compiled and issued by the Tokyo Chamber of Commerce, Japan.

These rules are accompanied by the "Procedures for Testing and Inspection for Wools and their Manufactured Goods" adopted by the Japanese Government Woollen Mills. These, compared with the Bradford Conditioning House regulations, are laid down on almost precisely parallel lines. The order in which the tests are undertaken are the same generally and in detail the tests themselves vary but slightly.

British Cotton Growing Association.

Report of proceedings of the Twenty-eighth Annual Meeting of Shareholders, held Friday, 26th May 1933, in Manchester. Records an increase in the total quantity of cotton produced in Empire fields.

GENERAL ITEM

ROAD SURFACING EXPERIMENTS WITH JUTE

(Note issued by the Indian Jute Mills Association)

An experiment of interest to the public has been undertaken recently by the Indian Jute Mills Association, involving the use of jute cloth in road surfacing. The work was carried out in January 1933 by Messrs. McLeod & Co., agents for "Colfix," on a stretch of Strand Road to the south of Outram Ghat. The process briefly is that the road surface, after being scraped and cleaned, is coated with bitumen; it is then laid with jute fabric—in this case 40"/8 oz. hessian—which is thoroughly rolled to make it adhere to the road surface. The fabric is then again coated with bitumen, covered with a layer of fine stone metal, and rolled so that the upper coating of bitumen penetrates the cloth and forms a solid mass with the bitumen underneath, and at the same time the stone chips adhere to the bitumen and fabric, producing the wearing surface.

Experiments on similar lines have, it is understood, been carried out in Germany and elsewhere, with the object of finding an additional outlet for jute goods. "An experimental stretch of road which was built with jute last summer near Neckars, Ulm"—states a report on one of these experiments—"is behaving exceptionally well, and in fact retains a better appearance than another stretch of road which was built at the same time without jute cloth. This latter, a tar road, has sweated considerably during the hot weather, so that split and sand have had to be strewn on it from time to time. The jute stretch, on the other hand, has so far remained perfectly dry and has needed no repairing. A few weeks ago the whole of the road, with the exception of the jute stretch, had, indeed, to be treated with tar and gravel, and the cost of this work has amounted to as much as the additional cost for building it with jute cloth would have been. It is therefore an established fact that the employment of jute cloth in road building renders the road more durable."

The Strand Road experiment has been undertaken with the co-operation of the Chief Engineer to the Public Works Department of the Government of Bengal, who has been good enough to supply the road roller and the stone metal required for the purpose.

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PROCEEDINGS Annual Conference of the Institute*

Harrogate, 7th, 8th, and 9th June 1933

Conference Proceedings in Room 1, 8th June

The Chairman, Mr. C. M. Whittaker, referred generally to the subject of Finishing, upon which each paper to be presented had a bearing. British dyers and finishers, whilst at the top of the tree, were always in pursuit of the wheel of fashion. He instanced examples of the changes to be made and problems presented which came regularly to the finisher for solution. He also gave a brief survey of textile research work now going on in this country and called on Mr. Delph to present the first paper.

QUANTITATIVE RESEARCH ON THE DYEING OF VISCOSE YARNS

By J. BOULTON, A. E. DELPH, F. FOTHERGILL and T. H. MORTON

Chairman Mr. C. M. WHITTAKER

A review of the literature on direct dyeing reveals that, while much work has been done on the physico-chemical nature of solutions of the dyestuffs, very little accurate quantitative work appears to have been done on the absorption of dyestuffs by cellulose.

An attempt has been made to study the process of dyestuff absorption by cellulose, usually in the form of viscose yarn, in a strictly quantitative manner. In the following pages a summary of the results so obtained will be given.

I—ESSENTIAL TECHNIQUE

In order to proceed with a quantitative study of the dyeing process two essential requirements must be met—

- (1) The employment of suitable dyestuffs in a chemically pure state.
- (2) The development of methods for determining the purity of these dyes and for their convenient estimation in the course of absorption experiments.

Commercial dyes may, and in general do, contain large quantities of organic and inorganic impurities and diluents, which must be removed in order to obtain a material suitable for quantitative investigation. The importance of this purification will be clear when it is realised that, for example, the usual brands of Sky Blue FF contain but 20% of the colour itself; the remainder, which is composed of inorganic salts together with some coloured organic material, is sufficient to render invalid any analysis depending on the usual gravimetric or colorimetric methods.

* This issue contains certain of the Papers read at the Conference, *in extenso* with the discussions that ensued. Other Papers will appear in subsequent issues.

In the preparation of pure dyes it was deemed best to take such concentrated dyes as the makers could supply, and then by suitable methods to separate the individual colour in a chemically pure form. The three colours chosen for the present work were Benzopurpurine 4B (Colour Index, No. 448) and Sky Blue FF (Colour Index, No. 518), representative of the unlevel dyeing direct dyes, and Chrysophenine G (Colour Index, No. 365), representative of the level dyestuffs. The choice of these dyes was guided not only by their dyeing properties but also by the fact that their molecular constitution is well known and established, so that their purity could be confirmed by analytical methods, and further that they could readily be estimated in the form of dyeings on yarn.

Purification of Dyestuffs

Most of the available published methods of purification may be criticised on the ground of an ill-defined final product. These methods are discussed by Robinson and Mills¹, who recommend a method of purification which has, in broad outlines, been followed in this work.

The dyes were first repeatedly salted out from aqueous solution by means of sodium acetate. Removal of electrolyte followed by recrystallisation from aqueous alcohol in the case of Benzopurpurine 4B and Chrysophenine G, and by extraction with alcohol in the case of Sky Blue FF, since it was found impossible to induce this dye to crystallise.

Estimation of Purity

It was found possible to estimate Benzopurpurine 4B and Sky Blue FF by reduction with titanous chloride, according to the method of Knecht and Hibbert². Chrysophenine G, however, behaves anomalously with this method, indicating consistently a purity of about 91%. It seems clear that with this dyestuff the reduction does not completely follow the course expected by Knecht and Hibbert.

The estimation of the total sodium content of the dyes by conversion to sulphate has been found to afford an accurate method of assay, which very sensitively reveals the presence of inorganic impurities.

A summary of analytical results obtained with the purified dyestuffs is given in Table I.

Table 1

Dyestuff	Purity (%)	
	By Titanous Chloride	By Sodium Content
Benzopurpurine 4B	99.5	100.2
Chrysophenine G	Not applicable	99.6
Sky Blue FF	100.7	99.2

It is not generally realised that many direct dyes are very hygroscopic. In Table 2 is shown the amount of moisture absorbed by the three purified dyestuffs from an atmosphere of 60% relative humidity.

Table 2

Absorption of Moisture from an Atmosphere of 60% R.H. at 18° C.

Dyestuff	Moisture Absorption (g/g Dry Dye)			
Benzopurpurine 4B	0.163
Chrysophenine G	0.077
Sky Blue FF	0.217

Neither of the methods used for the estimation of the purified dyestuffs is critical towards isomeric coloured substances, but dyeing experiments indicate that the samples of purified dyes are substantially free from such impurities.

All commercial samples of Sky Blue FF which have been examined contain a red impurity which is obvious in dyebaths approaching exhaustion; this impurity is removed preferentially and almost completely during the course of

purification, so that traces only can be detected colorimetrically in very highly exhausted dyebaths prepared from the purified material.

Ultramicroscopic Behaviour

Solutions of these preparations of Benzopurpurine 4B and Chrysophenine G in water are optically empty when examined with the ultramicroscope, while solutions of Sky Blue FF show some ultramicros. It is not, however, certain whether these particles are dyestuff aggregates or an adventitious impurity.

Colorimetric Estimation of Dyestuff

Chemical methods for estimating the amount of dyestuff absorbed or remaining in the dyebath in a long series of absorption experiments are unsuitable by reason of their tedious nature and the amount of material required.

Measurements of sufficient accuracy of the concentration of solutions of dyes have been found possible with a Klett colorimeter of the Dubosc type. In a simple dyeing the amount of dyestuff absorbed is easily determined by an estimation of the residual dye in a carefully prepared dyebath. There is, however, a more complicated absorption system in which two yarns are dyed simultaneously in the same bath, and here it is necessary to estimate the dye taken up by either yarn separately. To meet this case a method has been developed from some observations of Ratelade and Tschetvergov³. The dyestuff is stripped quantitatively from the fibre by extractions with hot 15% aqueous pyridine and estimated colorimetrically.

This stripping method is suitable for use with Benzopurpurine 4B and Sky Blue FF. In the case of Chrysophenine G the use of pyridine is not necessary since this dye is rapidly and completely stripped from yarn by hot water alone.

With suitable precautions the accuracy of the colorimetric method is high and dyeings may usually be repeated with a maximum inaccuracy of 1–2 per cent.

Dyeing Method

In conducting dyeing experiments capable of duplication it is essential to maintain an accurate control of temperature and to prevent evaporation. These conditions are fulfilled by conducting the dyeing in small wide-mouthed glass-stoppered bottles immersed to the neck in a thermostat. It has been found that with experience 1 g. of yarn can be dyed in 40 cc. of solution in a bottle of 100 cc. capacity in such a way as to avoid false results due to entanglement of the yarn into a compact mass, and yet with adequate agitation.

The yarn for the absorption experiments was thoroughly scoured, washed free from soluble matter, and then usually employed in the form of 1 g. skeins. In any one series of absorption experiments precaution was taken to ensure that all the small 1 g. slips were taken from the identical yarn comprising one large skein.

In the present work all volumes of dyebaths and quantities of colour and assistants are referred to a dry weight of yarn calculated from a conditioned weight by means of an average regain value.

By employing the technique sketched here dyeings of duration of a few seconds to many hours could be accurately reproduced on any given supply of yarn.

II—SUMMARY OF RESULTS

The theoretical interpretation of many of the quantitative data on dyeing appearing in the literature is rendered difficult by neglect by the authors of some important factor. As examples may be cited Weltzien⁴ and Schramek and Götte⁵ who apparently dye for an arbitrary time and use dyeing materials to which exception may be taken.

Further, the published theoretical interpretations of experiments on the dyeing of cellulose appeared to offer little help in the planning of the researches summarised here, for many investigators seemed to be building on very insecure

experimental foundations. Thus the corner stone of the colloidal theory of substantive dyeing as stated by Haller and Russina⁶ is a fixed polydispersity of the dyestuff together with the postulate that there is an optimum particle size for absorption by the fibre. A critical examination of the literature of this phenomenon of polydispersion in dye solutions leads, however, to a conviction that typical manifestations such as those recorded by Weltzien and Götze⁷ are due rather to foreign coloured impurities in the dye samples employed than to some subtle colloidal behaviour.

It has proved to be of more value therefore to build on the secure foundation of experience gained in the dyeing of rayon. In the earlier days of the rayon industry it was assumed that all direct cotton colours would be suitable for use with viscose yarns, but this was soon observed not to be the case, and in 1920 Wilson and Imison⁸ published a list of level, unlevel, and intermediate dyeing direct dyes. This work has been greatly extended by C. M. Whittaker⁹ who has not only classified a large number of dyes but has also devised several methods for a rapid determination of the dyeing properties of any dye. Two important facts emerge from this work which must be explained by a complete theory of the dyeing process.

(1) In dyeing for a fixed time those dyes which show a maximum affinity at a low temperature are level dyeing, whilst those which show a maximum affinity at a high temperature (90°) are the most unlevel.

(2) The dyeing process is more rapid at a given temperature with a level than an unlevel dyestuff.

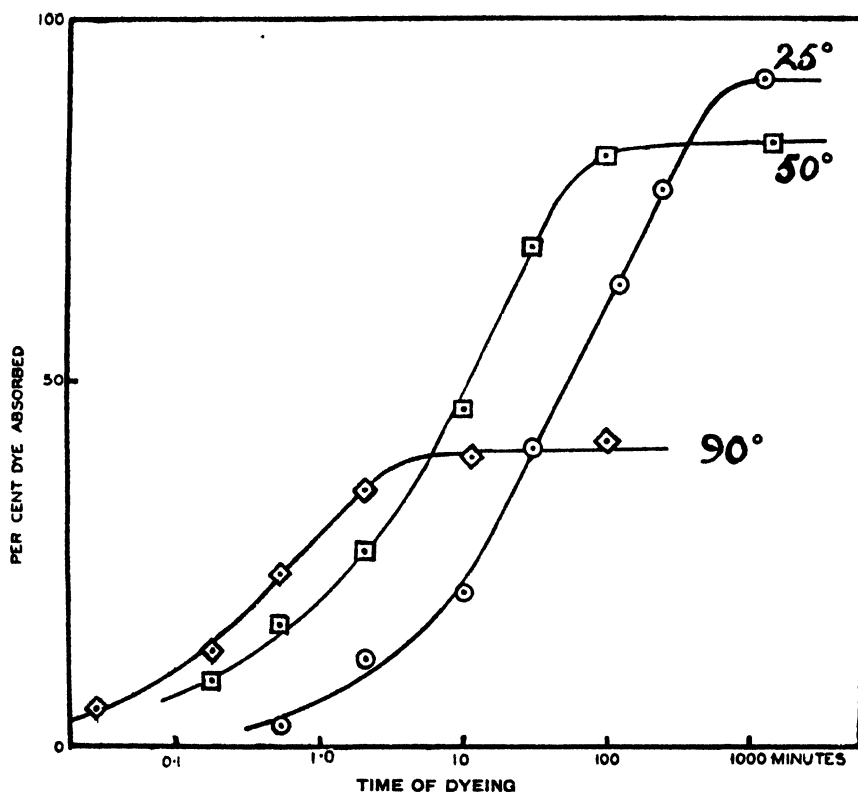


FIG. 1.—Absorption of Chrysophenine by a 300/36 viscose from a 40-volume bath containing 0.2% dye and 5% salt.

It is clear from these conclusions that time, usually neglected by previous investigators, is an important factor in the dyeing process. For this reason a study has been made of the kinetics of the dyeing process.

Dyeing Kinetics of Rayon

A series of absorption-time curves has been obtained for the three pure dyestuffs on three viscoses of varying filament denier, a fine filament stretch-spun Lilienfeld viscose yarn, and a stretch-spun cuprammonium yarn.

A typical set of absorption curves is given in Figure 1, which refers to the absorption of Chrysophenine by a 300/36 viscose. These curves are similar in shape to those obtained for all the yarns with the several dyestuffs.

Several important points emerge from a study of this series of curves.

(1) For any one curve, where temperature, yarn, and initial composition of the dyebath are maintained constant, the absorption velocity decreases with increasing time, until an equilibrium absorption is reached. This equilibrium, dependent on the composition of the bath, may be reached when little or practically all the dye originally present has been absorbed.

(2) The speed of attaining this equilibrium, with other conditions constant, varies with the yarn. If curves are plotted with a logarithmic time scale those for different yarns are similar in shape, being merely displaced on the time scale. The kinetics of dyeing are therefore similar for all the yarns, differing only in a velocity factor. The shapes of the curves are similar to that given by Hill¹⁰ for a process of true diffusion into a cylinder of material from a solution of constant concentration, suggesting that a diffusion process basically controls the kinetics of dye absorption.

(3) The observed equilibrium absorption for a given set of conditions is virtually independent of the yarn employed. Final equilibrium absorptions at 90° for 40 volume dyebaths containing 5% of sodium chloride and 0.3% Benzo-purpurine 4B, 0.2% Chrysophenine G and 0.12% Sky Blue FF respectively are given in Table 3.

Table 3
Equilibrium Absorption by Various Yarns

Yarn	Dyestuff Absorbed (%)			
	Benzopurpurine 4B	Chrysophenine G	Sky Blue FF	
Viscose, 300/36 ...	99	40	...	82
„ 150/40 ...	98	40	...	83
„ 150/72 ...	98	39	...	82
Durafil, 105/120 ...	99	42	...	83
Cuprammonium 120/90 ...	98	41	...	83

It is probably permissible to generalise from these results and to state that the *equilibrium* affinities for direct dyes of all normal regenerated cellulose rayon yarns are very nearly identical.

(4) The speed of dyeing varies considerably from one yarn to another. The time required to reach an absorption equal to half the final equilibrium value has been chosen as giving a convenient measure of the velocity of dyeing, and some values are given in Table 4 for the same dyeing conditions as in the previous paragraph.

Table 4
Times of Half Dyeing

Yarn	Time of Half Dyeing	
	Chrysophenine G	Sky Blue FF
Viscose, 300/36 ...	22 seconds	2.1 minutes
„ 150/40 ...	28 „	2.6 „
„ 150/72 ...	28 „	3.1 „
Durafil, 105/120 ...	19 „	3.9 „
Cuprammonium, 120/90	3.2 „	8.3 seconds

The data given in this table illustrate the following generalisations—

(a) The speed of dyeing is controlled by factors in addition to the relation of surface to bulk of the filaments of the yarn. The enormously greater speed of dyeing of stretch-spun cuprammonium yarn is probably related to a peculiarity in its fine structure which will be referred to later. The variation in the viscose series is probably bound up with the fact that the cross section of this yarn is not homogeneous. Preston¹¹ has demonstrated the existence of a tough, highly oriented "skin." All dyestuff passing to the interior of the yarn must necessarily pass through the tough outer zone, which may be expected to vary in properties and extent from yarn to yarn.

(b) The rate of dyeing of unlevel is less than that of the level dyes.

(c) The *relative* differences in the dyeing properties of a series of yarns tends to be greater with unlevel than with level dyes.

The Absorption of Dye by a Previously Dyed Yarn

If a yarn is dyed to equilibrium and is then transferred to a dyebath richer in dye, it behaves kinetically in a manner similar to undyed yarn. There is a very rapid initial absorption of colour followed by an increasingly slower absorption until finally the new equilibrium is reached, as might be expected if the dyeing process is essentially an absorption of dye on the surface of the filament followed by a diffusion of the excess into the interior of the yarn.

Dyeing Properties of Modified Cellulose

150/40 viscose has been subjected to various treatments, and dyeing kinetic curves determined for the yarns so modified.

The treatments were as follows—

(a) Treated with dilute sulphuric acid.

(b) Over-bleached with neutral (pH 7.0) hypochlorite.

Treatments (a) and (b) each occasioned a loss in wet tenacity of approximately 60 per cent.

(c) Treated with 4% sodium hydroxide solution at 20° for 15 minutes.

(d) Heated in a closed weighing bottle in an oven at 145° for 4 hours.

The equilibrium absorption, time of half dyeing, and water imbibed on complete wetting, for the modified yarns are given in Table 5.

Table 5
Dyeing Behaviour of Modified Yarns

Treatment	Water		Chrysophenine G		Sky Blue FF	
	Imbibition	(g/g Dry Yarn)	Time of Absorption	Half Dyeing (%)	Time of Absorption	Half Dyeing (%)
None	1.14	..	12 sec.	47	69 sec.	83
Alkali	1.26	..	3.5 "	47	41 "	82
Acid	0.94	..	12.5 "	47	102 "	82
Hypochlorite ...	0.95	..	21 "	27	420 "	58
Heat	1.01	..	--	..	87 "	84

These results may be summarised—

(1) Degradation by oxidation involves a marked decrease in the equilibrium affinity of cellulose.

(2) Degradation by acid, and heat and alkali treatment have no influence on the equilibrium absorption of cellulose.

(3) In those cases where treatment does not affect the equilibrium absorption the speed of dyeing is closely related to the swelling of the yarn in water.

Diffusion of Dyestuff

As noted above, the form of the absorption-time curve suggests a diffusion process, which can only refer to the migration of the dye from the surface to the interior of a filament. This migration can be followed by an examination of the cross-sections of yarn dyed for varying periods. After dyeing for a few

seconds the periphery of the section is seen to show a thin well-defined line of colour. Later the dye is seen advancing into the interior with a diffuse advancing edge, and finally, at equilibrium, the section is sensibly uniformly coloured.

The speed of diffusion is obviously connected with the speed of dyeing, and if there is a correlation between level dyeing properties and speed of dyeing there should be one also with speed of diffusion. This has been confirmed by rough comparisons of the speed of diffusion of a number of dyes within cellulose. Sheet cellulose—"viscabelle"—clamped between two plane surfaces was immersed in

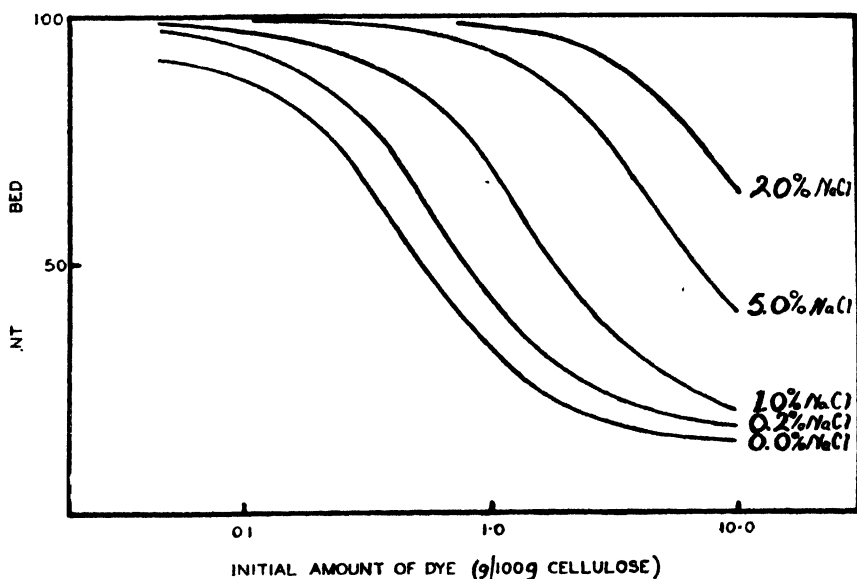


FIG. 2 Equilibrium absorption of Benzopurpurine 4B cuprammonium yarn from a 40-volume bath at 90° C.

a solution containing 0.025% commercial dyestuff and 0.25% salt at 95° for six hours. Now all dye within the sheet must have migrated from the edge in contact with the solution, so that if the greatest distance of visible dyeing from the cut edge is measured, this quantity will be a measure of the speed of diffusion. The results of this experiment are given in Table 6. It will be seen that those direct dyes which diffuse fastest are also those which possess the greatest levelling properties.

Rough estimations show that these diffusions correspond to diffusion coefficients of the order of 10^{-8} cm.²/second. Accurate determinations of the free diffusion of the purified dyestuffs in water at 25° have yielded diffusion constants for the three purified dyes of the order of 3×10^{-6} cm.²/second, so that the rate of migration of dyestuff within the cellulose is very much smaller than in water.

Table 6
Penetration of Dyestuffs into Sheet Cellulose in 6 hours at 95°

Dye	Penetration	
	Parallel to Direction of Extrusion of the Sheet	Perpendicular to Extrusion of the Sheet
Methylene Blue	2.43 mm.	2.17 mm.
Icyl Orange R	1.48 "	1.38 "
Chlorazol Fast Orange G	1.55 "	1.18 "
Chrysophenine G	1.03 "	0.92 "
Pyrazol Orange 2R	0.49 "	0.42 "
Sky Blue FF	0.31 "	0.26 "
Benzopurpurine 4B	0.26 "	0.22 "
Chlorantine Fast Blue GLL	0.25 "	0.20 "
Chlorantine Fast Blue 3GLL	0.11 "	0.11 "

It will be noticed that the speed of migration of the various dyestuffs is different in different directions within the cellulose sheet; this is probably to be related with the known preferential orientation of the molecular chains in the direction of extrusion of the sheet into the coagulating bath. This dependence of rate of diffusion upon fine structure may also be deduced from dyeing kinetics previously given. It was found that, for example, the fine filament Lilienfeld yarn absorbs Sky Blue FF more slowly than does a coarse viscose (Table 4).

Equilibrium Absorptions

A series of determinations were made of equilibrium absorptions of the purified dyes by cuprammonium yarn with varying amounts of salt present in the system. Cuprammonium yarn was chosen for this series of experiments since only a short time is required to set up a true equilibrium between bath and yarn. According to present knowledge the equilibria so determined will represent in addition the behaviour of viscose with reasonable accuracy. In Figures 2 and 3 are given absorption isotherms for Benzopurpurine 4B and Sky Blue FF at 90°. Curves for Chrysophenine G are similar to those of Sky Blue FF, with

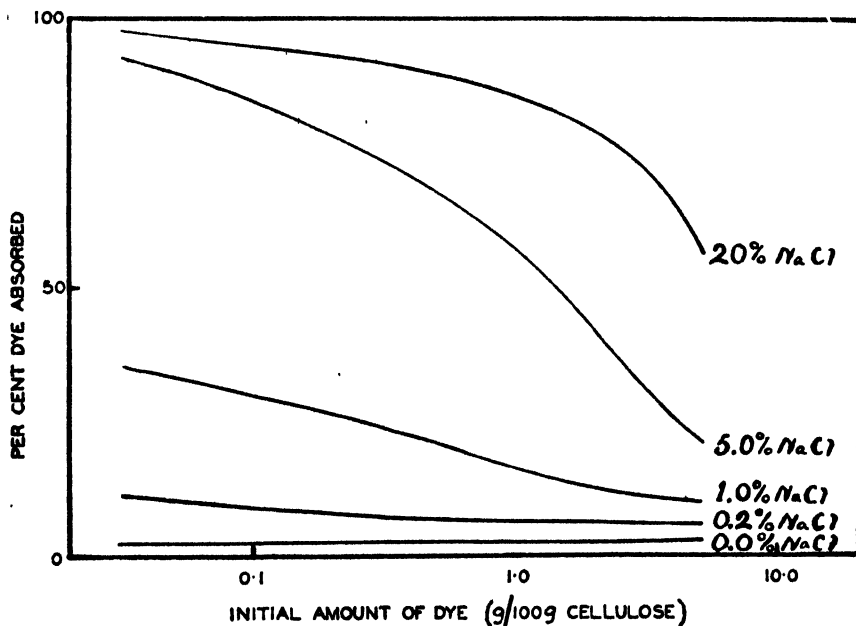


FIG. 3.—Equilibrium absorption of Sky Blue FF by cuprammonium yarn from a 40-volume bath at 90° C.

the exception that for a given amount of salt absorption of dye is smaller. The results are given in the form of the percentage exhaustion of a 40 volume dye-bath, and the quantities of sodium chloride and dye as fractions of the dry weight of cellulose employed. It is clear, however, that the concentrations, dye on yarn and dye in solution, derived by a simple calculation from these results are valid equilibrium data independent of the relative amounts of the solid and liquid phases present.

In the absence of salt both Chrysophenine G and Sky Blue FF show a zero absorption. Benzopurpurine 4B, on the other hand, shows a distinct substantivity in the absence of salt. An extrapolation of the results shows that this might easily be due to a salt effect corresponding to a salt concentration in the dyebath of a few parts per million which may arise from accidental contamination or from the ionic nature of the dyestuff itself.

The isotherms obtained at temperatures lower than 90° with a given amount of salt are similar in shape to those obtained at the higher temperature with a greater amount of salt.

When equilibrium measurements were made on similar dyebaths containing univalent metal ions derived from sodium chloride, sodium nitrate, sodium sulphate, potassium chloride, and potassium nitrate of equal ionic concentration it was found that the equilibria were approximately equal, although measurable differences, of the order of a few per cent. were observed. Polyvalent ions, as magnesium and aluminium, of corresponding concentrations gave much higher values for the absorption.

With the three dyes employed the equilibrium appears to be completely reversible, provided sufficient time is allowed for a true equilibrium to be established. Thus, in two otherwise similar systems, in which initially all the dye was on the fibre and in solution respectively, the final partition of colour between cellulose and bath was found to be identical.

The absorption of dyes from a dyebath containing two dyes presents an interesting case. By a modification of the colorimetric technique it was found possible to estimate separately the quantity of each dye absorbed. Less of either dye was taken up than if the other had been absent from the system, indicating a competition for available points of attachment. Very roughly the equilibrium data could be interpreted as a partition of the whole of the internal surface of the cellulose between the two dyestuffs.

The Absorption of Dye by 150/21 and 150/36 Viscose

The appearance of a dyed yarn clearly depends on factors other than the dyestuff content of the material, for the light which reaches the eyes is compounded of reflected white light and coloured light which has passed through various thicknesses of dyed cellulose before being reflected.

A consideration of the behaviour of say, 150/21 and 150/36 viscose, affords a clue to the relation between appearance and dye content of a given dyeing.

A thin undyed knitting of 150/36 yarn appears whiter than one of 150/21 yarn because the former presents a larger number of reflecting surfaces to a ray of light passing through it, reflecting therefore a greater portion of the incident light. Similar knittings folded to many thicknesses will appear identical since they will now possess the same number of effective surfaces, for there is sufficient thickness of fabric to reflect all the light. It is clear, however, that the optical path in the coarse filament yarn, although geometrically similar, is longer than in the fine filament yarn. If now the yarns are dyed with the same amount of colour the 150/21 viscose will appear darker since the reflected rays here passed through a greater thickness of dyed material, and have therefore suffered greater selective light absorption. To give the same apparent depth of shade on both 150/21 and 150/36 viscose the selective absorption must be identical in the two cases; that is the ratio of concentrations of dye must be inversely proportional to the lengths of the corresponding paths of the light within the two yarns. This

ratio is the ratio of the corresponding linear dimensions and is equal to $1 : \sqrt{21/36}$ or $1 : 0.76$. This ratio of the quantities of dye required to produce the same apparent shade on the two yarns corresponds reasonably well with that determined experimentally, 0.90, having regard for the nature of the assumptions.

The above reasoning depends on the assumption of a geometrically similar outline of cross-section of the two yarns. If the outlines are not similar, it is clear that a yarn with a more indented cross-section will behave visually as a yarn of finer filament denier and conversely.

Interesting aspects are presented by the study of the simultaneous dyeing of a rapid dyeing 150/36 viscose and a slower dyeing 150/21 viscose. Quantitative results of a study of such a system, containing equal quantities of either yarn are given in Tables 7 and 8.

Table 7

Absorption at 90° from a 40 vol. Bath containing 0.2% Sky Blue FF and 10% Sodium Sulphate by 150/21 and 150/36 Viscose

Time of Dyeing					Absorption (mg. Dye/g. Cellulose)		Ratio of Absorptions	
					150/36	150/21		
5 minutes	...	...	...	...	0.47	0.37	...	1.27
20	"	...	...	...	0.78	0.58	...	1.35
30	"	...	...	...	0.93	0.71	...	1.31
60	"	...	...	...	1.08	0.98	...	1.10
75	"	...	...	...	1.19	1.07	...	1.11
120	"	...	...	...	1.24	1.21	...	1.03
170	"	...	...	...	1.22	1.22	...	1.00

Table 8

Absorption at 90° from a 40 vol. Bath containing 0.2% Chrysophenine G and 10% Sodium Sulphate by 150/21 and 150/36 Viscose

Time of Dyeing					Absorption (mg. Dye/g. Cellulose)		Ratio or Absorptions	
					150/36	150/21		
0.5 minutes	...	...	...	...	0.24	0.22	...	1.08
1	"	...	...	...	0.31	0.26	...	1.20
2	"	...	...	...	0.40	0.36	...	1.12
3	"	...	...	...	0.44	0.41	...	1.07
10	"	...	...	...	0.47	0.45	...	1.04
30	"	...	...	...	0.46	0.47	...	0.98
40	"	...	...	...	0.48	0.46	...	1.04

In the early stages of the dyeing process the rapidly absorbing fine filament yarn takes up an excess of the dye sufficient to cause it to appear a deeper shade than the coarser yarn. When the final equilibrium has been set up, however, and identical amounts of dye have been taken up by the two yarns the coarser yarn appears the darker by reason of the optical effect discussed above. There is therefore an intermediate period of dyeing when both yarns appear equally dyed, although, of course, the dye contents of the fibres are very different.

It will be noted, as might be expected, that the time required for the level dye, Chrysophenine G, to attain substantial equilibrium is very much less than that taken by the unlevel dye, Sky Blue FF.

Dyeing of Unlevel Viscose

Although with good modern rayon the variation in affinity for direct colours is not great, yet by careful selection dyeing extremes of the same yarn can be found. An examination of the curves for the simultaneous dyeing of such unlevel viscose shows that the kinetics are very similar to those obtained for the simultaneous dyeing of 150/36 and 150/21 viscose quoted above. One yarn rapidly takes on an excess of the dye, but when final equilibrium is attained they are equally dyed. Since here the process is not complicated by optical differences between the yarns the originally unlevel dyeings become identical in appearance at equilibrium.

In considerations of the apparent levelness or unlevelness of dyeings it is desirable to know what differences in dye content can be distinguished visually. It is clear that comparatively large relative differences in dye content could not be detected in a very light or a heavy black shade. Expert opinion agreed that the smallest detectable difference would be found with a medium blue shade. A series of dyeings with Sky Blue FF was prepared and it was found that an expert colour-matcher could just detect with reasonable certainty a difference of dye content of 2%. A difference in dye content of 5% seemed to be the smallest plainly distinguishable difference. It is probable that with, say, a pure yellow like Chrysophenine a perceptible difference would be greater than 2%, whilst with mixtures of dyes a *relative* difference of less than 2% would be apparent.

Whittaker's Classification of Dyestuffs

C. M. Whittaker⁹ has employed two main methods for classification of direct dyestuffs according to their levelling properties. These tests can be justified by the quantitative results given in this paper.

(1) The "Temperature Range Test."

Essentially this test consists of dyeing for a fixed period, *e.g.*, 30 minutes, in a dyebath of fixed composition at various temperatures. Level dyes give a maximum depth of shade at low temperatures and unlevel ones at high temperatures.

It has already been pointed out that the absorption curves of Chrysophenine G (Figure 1) are of the same general shape as those to be expected with any dye, with the exception that the more uneven the dye the more the curves will be displaced to the right along the time axis. Thus, dyeing with a very level dye, a medium, and an unlevel dye for 30 minutes may be taken as being kinetically equivalent to dyeing with Chrysophenine G for, say, 2 hours, 10 minutes, and 1 minute respectively. The dyestuff absorption under these conditions is represented schematically in Figure 4, which also represents the working of the Temperature Range Test.

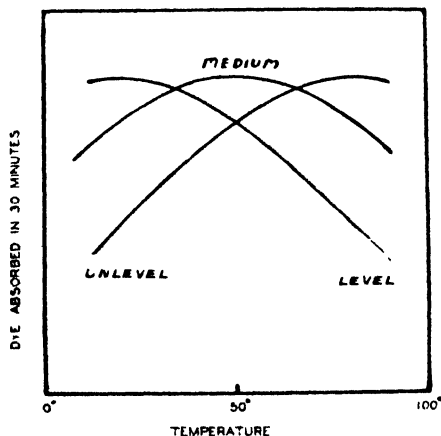


FIG. 4 Amount of dye of differing levelling properties absorbed in 30 minutes (schematic)

(2) The "Time Range Test."

This test, which is suitable for the classification of the extremely unlevel dyes, consists in observing the time required at 90° for knittings composed of a fast dyeing 150/36 and a slow dyeing 150/21 viscose to assume an apparent equality of shade, as discussed in the previous section. It is found that a longer period is required as the dye investigated possesses a greater degree of unlevel properties.

Apparent equality in shade on the two yarns marks the point when the optical difference of the filaments just renders ineffective the difference in dye content, and since this happens when the latter difference has a fixed value, it also marks the completion of a definite fraction of the whole absorption process. The time taken, then, to reach this stage is a measure of the speed of the dyeing process, so that the validity of the test is clearly related to the relative slowness of the diffusion of the unlevel dyes within cellulose as compared with level dyes (Table 6).

The Swelling of Cellulose

In a consideration of the dyeing process a knowledge of the amount of water absorbed by cellulose within the material itself is desirable. The measurements recorded here have been obtained by gravimetric and dimensional methods.

The imbibitions on immersion in water at 20° for the yarns whose dyeing behaviour has been recorded in Tables 3 and 4 are given in Table 9. Comparable figures for 150/40 viscose yarn modified by various treatment have been previously noted in Table 5.

Table 9
Inhibition of Water on Complete Wetting by Various Rayons

Yarn				Water Absorbed (g/g Dry Yarn)
Viscose, 300/36	...	...	...	1.18
" 150/40	...	...	...	1.12
" 150/72	...	...	...	1.06
Durafil, 105/120	...	...	...	1.02
Cuprammonium, 120/90	...	...	...	1.04

The swelling of cellulose at 90° in water and in any solution likely to be employed as a dyebath is substantially identical with that at lower temperatures in water.

Dry cellulose does not swell when immersed in an organic solvent, but if first wetted with water and then transferred to a miscible organic liquid such as alcohol or acetone there is obtained a preparation swollen with the organic liquid. By using this replacement technique Kistler¹² was able to obtain gels of many organic and inorganic substances in which the swelling medium was finally replaced by air. It has been found that the bulk swelling of sheet cellulose is reduced only to approximately 90% on replacement of water by acetone or alcohol, and to 65% by xylene.

The importance of swelling in the dyeing of cellulose is illustrated by some experiments of dyeing from non-aqueous media. It is found that previously dried viscose is completely unstained by an alcoholic solution of such direct dyes as Chrysophenine G, Chlorazol fast Helio BK and Chlorazol fast Orange G, whilst a viscose swollen with alcohol, prepared according to the above replacement method, dyes deeply in the same solution.

When cuprammonium yarn replaced viscose in such an absorption experiment an interesting difference was noted. Here the unswollen yarn was found to have an affinity on prolonged dyeing not far short of the swollen material, although the rate of absorption was much smaller than that of the latter preparation.

Dyeing experiments similar to these have been carried out by Ratelade and Tschetvergova³, who, however, do not seem to have noticed the swelling behaviour nor to have realised the theoretical implications of the work.

III—DISCUSSION

The evidence which has been given in the experimental part of this paper indicates that possibly the most important factor to be considered in connection with the dyeing process is speed. When, with normal conditions of dyeing, an uneven effect was achieved employing an unlevel dye the effect was generally dismissed as a difference in "dyeing affinity" of the yarn, and it was tacitly assumed that the darker dyeing material tended to absorb more dye than the light dyeing yarn.

When the quantitative experimental work on the absorption of direct dyes was begun it was anticipated that the final absorption of dyestuff would vary from yarn to yarn in the way that the absorption of moisture from a humid atmosphere¹³ and alkali from solutions of sodium or barium hydroxide¹⁴ varies with the nature of the yarn. It was surprising, therefore, to find that the absorption of direct dyestuffs appeared virtually independent of the nature of the regenerated cellulose composing the yarn. Further investigation showed that the dye absorption was still more removed from the moisture absorption phenomena for the equilibrium attained was fully reversible; hysteresis was not found with cuprammonium yarn.

Since there is little or no practical variation in the final equilibrium absorption, the cause of uneven dyeing with rayon must be sought in the variability in its speed of dyeing. A light dyeing yarn absorbs dye more slowly than a greedy yarn, although both tend towards the same final absorption. This fact leads to the conclusion that any dye, however unlevel, may be used in the dyeing of uneven material with the production of uniform results provided a sufficient length of time is given to the dyeing process. This is, in general, in harmony with dyehouse observations, although here long period dyeings may have other practical limitations.

The mode of operation of levelling agents, such as β -naphthol, as components of the dyebath, is to hasten the attainment of equilibrium; the precise mechanism of their action is still obscure.

In the past, when precise quantitative measurements have not been available, this uniformity of equilibrium absorption has been obscured by the optical behaviour of the yarns. A coarse and a fine filament viscose containing exactly the same amount of dyestuff appear as if the former were much more heavily dyed, and it has been often assumed that it had absorbed more colour and was therefore possessed of a greater "affinity." This, however, is not so and the effect is purely optical.

The foregoing experimental data enable a sketch to be made of a working hypothesis of the dyeing process, and possibly a clearer view to be obtained of the fine structure of cellulose.

The field of the structural theory of cellulose has recently been dominated by the X-ray crystallographers who have developed a complete micellar theory¹⁵ which, satisfactory in some respects, leaves many points in the behaviour of cellulose still unexplained. Thus it is difficult to see how a structure composed of non-swelling elongated crystallites can explain the cohesion of a viscose yarn when it has absorbed an equal weight of water by simple wetting, or, further the longitudinal contraction of a viscose yarn on immersion in a strongly swelling solution of sodium hydroxide¹⁶. These considerations suggest that the crystalline regions of the structure are not independent of one another.

The formulation of the now generally accepted long chain structure of the molecule of cellulose was first proposed by Haworth¹⁷ in 1928, who later by chemical means found 200 glucose residues in the chain of cotton cellulose¹⁸. This value must be regarded as a minimum when the nature of the method is considered. Accepting this value, however, the length of the molecular chain is 1000\AA , while the size of the crystalline aggregates of the cellulose structure, determined from the diffuseness of the interference points of the X-ray diagram, is given by Meyer and Mark¹⁹ as, length $150\text{--}200\text{\AA}$, and thickness $40\text{--}50\text{\AA}$. It seems probable then that one molecular chain may be a component of several crystallites or regions of crystalline arrangement.

The fine structure of, say, an oriented cellulose is probably best conceived as a three dimensional network of more or less parallel molecular chains, which are not necessarily straight since free rotation is possible at every glucosidic linkage, but which here and there fall into restricted regions of crystalline conformation. Some confirmation of this conception is to be found in the fact that

X-ray examination of the most highly oriented preparations of cellulose reveals the presence of a considerable proportion of "amorphous" material in addition to the crystalline aggregates. When such a structure is swollen by immersion in water, osmotic forces tend to cause the chains to move apart, but in the crystalline regions this is prevented by crystal forces, as is shown by the similarity in the X-ray diagram of wet and dry cellulose. In the intercrystalline regions the molecular chains will move apart during swelling until the osmotic forces are just balanced by elastic forces tending to restore the structure to its original configuration. Hysteresis in moisture absorption may be explained with this model by postulating that certain elements of structure are broken down during sorption and are only re-formed during desorption at a lower value of the swelling.

Between the crystallites, in the swollen condition, the molecular chains will form an open network through which small molecules may pass with ease. McBain and Kistler¹² have shown that unswollen viscose—Dupont's Cellophane—is almost completely impermeable to organic solvent molecules, whilst the swollen material is much more readily permeable to molecules of alcohol than to the larger ones of benzene. The average pore size in the swollen material is, therefore, but a few diameters of the benzene molecule. Large particles such as dyestuff molecules will have difficulty in migrating through these capillary spaces and will therefore diffuse slowly.

In cuprammonium yarn, as distinct from viscose, molecules of dyestuff are able to penetrate the unswollen material. Here the cellulose probably contains preformed capillary pores due to some special condition in the coagulation process. This phenomenon is probably analogous with that found in the ultra-filtration nitrocellulose membranes which, by coagulation in appropriate circumstances, may be made to have any desired pore size so as just to retain a Prussian Blue sol or a dextrin of low molecular weight²⁰. Round these larger pores in cuprammonium cellulose there is probably the normal fine structure sketched above.

In the normal cellulose structure the molecular chains in the intercrystalline regions and on the outer surface of the crystallites may be supposed to be ready to form molecular compounds by reason of the potential co-ordinating power of the three free hydroxyl groups attached to each glucose residue.

The substantivity of the direct cotton dyes is probably to be explained by the formation of co-ordinated molecular compounds between the colour molecule and a portion of the long molecular chain of cellulose. In this connection it is interesting to note that the majority of the cellulose dyes, such as benzidine colours, possess a thin elongated molecule, which may be supposed to lie along the cellulose chain when any co-ordination compound is formed. This last conclusion is in harmony with the dichroic behaviour of dyed cellulose fibres²¹. Thus a ramie fibre dyed with Congo Red is colourless when observed in polarised light with its length parallel to the plane of polarisation, and deeply coloured when its length is perpendicular to the plane of polarisation. The dye molecules, therefore, must, like the cellulosic molecular chains, be oriented with their long axes parallel.

The molecular compound between dyestuff and cellulose is, in general, not very stable. A comparison of the dyeing behaviour of the animal fibres and cellulose suggests the greater stability of the salt-like fibre-dye complex in the former case compared with the co-ordinated complex in the latter.

The cellulose-dye complex tends to be dissociated by water and, to a less extent, by alcohol. The affinity of the dyestuff for the water phase can be reduced by the addition of salt, as is shown by the general development of colloidal properties when salts are added to solutions of direct dyes. The presence of salt in the absorption system therefore favours an equilibrium displaced to give an increased amount of dye on the fibre.

The dyeing process may now broadly be sketched. Immediately the yarn is immersed in the bath the outside of the filament absorbs dye until it is in equilibrium with the solution. This is helped by the imbibition of the fibre; a considerable quantity of water is withdrawn from the bath and the dye dissolved in this is retained at the surface of the filament by a process analogous to ultrafiltration. The equilibrium is dynamic and the dye molecules tend to move from the dyed surface to the undyed interior under the influence of osmotic forces. As the surface loses dyestuff in this way more is removed from the bath to take its place, so that, in effect there is a migration of dye from the bath to the interior of the yarn. This process continues until every portion of the cellulose throughout its bulk is in equilibrium with the dyebath.

The speed of dyeing is clearly related to the ease of migration of the dyestuff molecules through the molecular pores of the cellulose structure. The great change in speed of dyeing with small changes in the total swelling of the structure has already been illustrated by the data of Table 5, and this suggests again that the pore dimensions are of the same order as the dimensions of the dyestuff molecule. It is probable that the fundamental difference between level and unlevel dyes is that the molecules of the latter diffuse with comparatively much less ease than the former through the fine pores of the cellulose structure.

Since all rayons investigated possess similar equilibrium affinities it may be assumed that the proportion of molecular chains in the cellulose available for dyeing is similar in all cases. It is hoped to compare the equilibrium absorptions of various forms or natural cellulose with that obtained for rayon, and so obtain possibly information as to differences and similarities in the fine structure of various forms of cellulose. The fall in the equilibrium absorption of rayon which has been degraded by oxidation (hypochlorite) is probably due to variation in the tendency of the available cellulose chains to form co-ordinate complexes with the dye molecules when the hydroxyl are replaced by carbonyl or carboxyl groups. The acid carboxyl groups will tend to repel rather than to unite with dyestuffs containing sulphonic acid groups; in this may possibly be found an explanation of the lowered equilibrium affinity. In the same way the presence of carboxyl groups may account for the enhancement of the absorption of basic dyes by cellulose after oxidation.

It is hoped to present in the near future a more detailed account of the experimental methods and results referred to in this paper.

SUMMARY

(1) The purified direct cotton dyes, Benzopurpurine 4B, Chrysophenine G, and Sky Blue FF, have been employed in a quantitative study of the dyeing of regenerated cellulose yarn.

(2) Dyeing proceeds to an equilibrium which is practically independent of the nature of the yarn.

(3) The principal difference between various rayons, and between light and dark dyeing yarn of the same denier, is to be found in dyeing speed.

(4) Treatment of viscose with caustic soda, prolonged heating, and degradation by acids, affects the speed of dyeing but not the equilibrium finally attained. Degradation by oxidation with hypochlorite substantially decreases the amount of dye absorbed at equilibrium.

(5) The level dyeing dyes as a class are absorbed more rapidly to equilibrium than the unlevel dyes.

(6) The kinetics of dyeing may be explained as a diffusion process. The rate of diffusion of unlevel dyes within cellulose is less than that of the level dyes.

(7) The equilibrium absorption varies with the dyestuff and the composition of the dyebath. With Chrysophenine G and Sky Blue FF there appears to be a zero absorption in the absence of salt.

(8) The speed of dyeing a yarn of given structure with a direct dye increases rapidly with the total swelling on wetting. In a series of rayons of varying

preparation, however, the fine structure is of more importance in determining the speed of dyeing than the degree of imbibition.

(9) By a replacement technique, viscose cellulose swollen with organic liquids has been obtained; in this form it is readily dyed by solutions of certain direct dyestuffs in alcohol or acetone, which do not dye the unswollen material.

(10) The optical behaviour of rayon, and the relation of appearance to dye content, is discussed.

(11) The observed phenomena have been embodied in a tentative theory of the dyeing process, and certain conclusions relating to the fine structure of cellulose have been recorded.

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DISCUSSION

In the discussion following the above paper, Mr. Lomax said that reference in the main had been to three dyestuffs; he would like to know how far it had been the lecturer's experience that other dyestuffs conformed to the conditions described? He also wished to point out that in one place it had been stated that speed was of great importance in dyeing and subsequently "that any dye, however unlevel, may be used in the dyeing of uneven material with the production of uniform results provided a sufficient length of time is given to the dyeing process." There seemed, to him, to be a lack of agreement between these two assertions.

Dr. T. H. Morton in reply said that the three dyestuffs particularised could be regarded as typical: so far no evidence had come to their notice to indicate that their results were anomalous. Any use of retarding agents in the dyeing of cotton would seem to be governed by difficulties of a mechanical nature; in such

cases the dyestuffs may have to dye off heavily dyed parts before ultimate equilibrium is reached.

Mr. A. E. Delph, said that it was altogether a matter of practical limitations in dyeing to equilibrium. The quicker the dyeing of viscose yarn, the more level the results usually obtained.

Mr. C. M. Whittaker, Manchester, said that he was not a cotton dyer but that in dyeing viscose rapid dyeing was helpful. He asked Mr. Lomax to note that Mr. Delph was dyeing to equilibrium—a stage rarely reached in bulk dyeing.

Mr. W. Harrison, in expressing his appreciation of the valuable paper of Mr. Delph, made some quotations from previous publications of 1911 (*J. Soc. Dyers and Col.*, 1911, 27, 279) in which the effects of pore size in fibres and particle size in dyestuffs was described. The deductions from this work were applied in 1919 to the case of viscose rayon dyeing. When one had two forms of viscose, one having pores larger than the other, any dyestuff which formed particles of molecular aggregates of a size in between the sizes of the pores in the two forms of rayon, would give unlevel dyeing. In taking a range of dyestuffs forming particles of diminishing size, one would expect that there would be an increase in affinity for the fine structure rayon which would at first give more level dyeing until the stage had been reached where the dye had a greater affinity for the fine structure rayon when one would again get unlevel dyeings. Such an effect actually takes place and indicates the need for classifying dyestuffs according to affinity for some selected form of cellulose instead of as level and unlevel dyeing dyestuffs. It is not difficult to select conditions which give level dyeing on one pair of different rayons and not on another pair. In the case of mixtures of dyestuffs of large and small particle size the small particle would move or diffuse the faster and get into the pores sooner, thus tending to increase the difference in affinity of the large particle dyestuff for the two different rayons. Whilst it is a fact that pure dyestuffs in the absence of salt form true solutions, a point established by Knecht and Batey (*J. Soc. Dyers and Col.*, 1910 or before), under practical dyeing conditions this is not the case, the molecules of dyestuff are undoubtedly associated to an extent unknown but in many cases very considerably, the particles being easily visible in the ultramicroscope. It is of particular interest that Mr. Delph's work rather confirms the opinions previously expressed by the writer and disproves the theory of Wilson and Ineson which correlated the molecular weight of the dyestuffs with their dyeing properties.

Replying to Mr. Harrison, Dr. Morton said, as viscose is impermeable in the unswollen condition to dye molecules having dimension of the order of 25Å by 10Å, but becomes permeable on swelling, it is suggested that the pores in the viscose are of the same order of magnitude as the dyestuff molecules, as in alcoholic solution the dyestuff is molecularly dispersed. Under these conditions it is inconceivable that dyestuff particles of a colloidal size can penetrate the viscose, further, in the case of different viscose yarns, where the differences are constituted by variations in pore size, there would tend to be differences in the speed of migration of the dyestuff and hence in the speed of dyeing rather than in the final absorption attained.

Mr. J. G. Williams, referred to the question of the fastness of dyes to washing. He was particularly interested in the effect of salt on the equilibrium between the cellulose and the dyestuff solution, and it appeared that the presence of some salt during washing would be very advantageous. Had this matter been the subject of any investigation, or was it to be investigated subsequently?

In answer to this, Dr. Morton said that salt in washing water tended to reduce the washing-out of dyestuffs. The very slow-dyeing direct dyes were not much subject to this objection but the dyer's difficulty was to secure level dyeing with such dyestuffs.

SOME OBSERVATIONS ON THE BEHAVIOUR OF VAT DYESTUFFS ON COTTON

By F. SCHOLEFIELD and H. A. TURNER

Chairman Mr. H. H. BOWEN

To the dyer and printer of cotton and rayon materials, the vat colours are of great importance by reason of the high degree of general fastness obtainable by their use. Where fastness to light, washing and bleaching is required, the vat dyestuffs are capable of producing, in a comprehensive range, dyeings of a degree of resistance not at present obtainable by any other class. The vat dyestuffs themselves, and particularly those of the anthraquinonoid type, are very inert chemically, being resistant to attack by acids, alkalis and oxidising agents. Indeed, from the chemical point of view, they may be regarded as being susceptible of ready modification only by strong reducing agents, particularly when these act in the presence of caustic alkalis.

In 1928, Scholefield and Patel¹ first drew attention to some apparently abnormal tendering and fading actions brought about by vat dyestuffs, and demonstrated the interesting fact that the members of the series most active in this respect were, in general, the yellows and the oranges. This evidence was summarised in the original papers as follows—

(1) "Orange and yellow vat dyeings on cotton are much more susceptible to the tendering action of light than those of other colours, especially blues and violets."

(2) "In mixtures of yellow (or orange) and blue vat dyestuffs on cotton, the fastness to light of the blue component is, in general, reduced by the yellow present."

(3) "Tendering of the cellulose material takes place during the dyeing process with vat yellows and oranges, if the material is exposed to light and air whilst saturated with the vat solution; or, if a second dyestuff—*e.g.*, Ciba Blue 2B—be present, this dyestuff may be wholly or partially destroyed."¹

(4) "When cellulose materials dyed with certain vat yellows or oranges are subjected in the dark to the action of hypochlorite solutions of ordinary bleaching strength (or weaker) for periods up to 45 minutes, no appreciable tendering of the material takes place. If the dyed material, saturated with hypochlorite, is exposed to the action of daylight or to the light from the carbon arc of the Fadeometer, tendering of the cellulose takes place when the material is dyed with certain vat yellows and oranges."²

Since the first publication of these observations, work on the subject has been continued in the Department of Textile Chemistry at the Manchester College of Technology, and in view of the appearance of a number of interesting and valuable papers by other workers dealing with one or other of these aspects of the special behaviour of vat dyestuffs, it has been thought advisable to take this opportunity of setting out in general terms the tentative conclusions to which we have been led by the results of experimental work carried out by various members of the staff, by students, and by Dr. E. H. Goodyear for whose very valuable assistance we are indebted to Imperial Chemical Industries Limited (Dyestuffs Group). It is intended that the fuller experimental details shall be published elsewhere.

The first significant observation to be considered is that the instances of tendering and fading described above are associated with the employment of yellow, orange and, to a lesser extent, red vat dyestuffs, in the dyeings. This has been confirmed by the work of Landolt,³ Whittaker,⁴ Nodder and Derrett-Smith,⁵ and others. Two possible explanations may be suggested. Firstly, that yellow and orange and, to some extent, red vat dyestuffs possess a common chemical grouping in their molecular structure which is absent in the rest of the

vat dyestuffs, and which is responsible for interaction with the cellulose substrate. Secondly, that these active dyestuffs are peculiar in their ability to absorb light of such frequency that it is able to supply sufficient energy to bring about the destructive changes. The one explanation does not, of course, necessarily exclude the other.

So far as the first explanation is concerned, if the widely differing constitutions of vat dyestuffs—anthraquinonoid, indigoid and sulphur—which are active, are taken into account, it is improbable that any specific atomic grouping is alone responsible. Moreover, if the constitutional formulæ (in so far as they are known) of a single one of these classes, the anthraquinonoid, are examined, it is very difficult to see in the yellows and oranges any common atomic grouping not found in the blues and violets.

In support of the hypothesis of a selective or specific light absorption as a condition of activity in the yellow or orange vat dyestuffs, measurements of absorption spectra upon dyed viscose sheets, by J. M. Preston and others, give evidence of strong absorption by the active dyes of light of wave-length between 3600–4000 Å. Strong absorption in this region does not occur with the vat blues and greens.

The connection between the marked chemical activity of the yellow and orange vat dyestuffs and their common property of absorbing light in the near ultra-violet can be interpreted in terms of the Quantum Theory.

According to this theory, radiant energy does not flow continuously from the source, but is sent out in very small detached quantities, or quanta. A whole quantum may be taken up by a molecule and used in various ways. The quanta, if they are the energy of light of a single wave-length, are all the same size, but they vary in size according to the wave-length of the light. The amount of energy in the quantum from light of a frequency ν is always given by the product $h \nu$, where h is a universal constant. Since the frequency of light increases in moving from the red to the violet end of the spectrum and on through the ultra-violet rays, it can be seen that the quanta of light energy progressively increase as we go through the spectrum in the direction red to violet. Thus, when a quantum of blue light is absorbed by a molecule, more energy is imparted than when a quantum of red light is taken up.

When a quantum of light is absorbed by a molecule, the energy $h \nu$ may be utilised in various ways. It may—

- (a) excite the molecule, that is, alter the arrangement of the electrons in it so that it assumes an unstable condition from which it will try to revert to its original condition. As it does so, it will endeavour to dispose of some or all of its extra energy, either by passing it on to other molecules with which it comes into contact, by undergoing chemical changes or reactions with other molecules, or by sending it out again as a quantum of light energy of the same size, or smaller (*i.e.*, as light of an equal or less frequency than the exciting light).
- (b) decompose the molecule.
- (c) increase the kinetic energy of the molecule, or in other words increase its average speed of movement so that when the molecule comes into collision with a slower moving molecule it will have more energy to give up to it.

In applying these ideas to the explanation of why chemical actions occur, the further assumption is made that such reactions will not take place unless the energy content of the molecule is increased above a certain minimum. In general one quantum of energy from long wave-length light, say red or yellow, is not sufficient to allow this level to be attained in one step, and if the molecule has to get its energy in more than one step, either by absorbing two or more quanta, or by collisions with molecules of high kinetic energy (and it runs the risk of losing some of its own energy in between two such collisions), it will be

seen that the chances of chemical action are materially reduced. This corresponds to the generally substantiated fact that light in the blue, violet and ultra-violet regions of the spectrum is most capable of bringing about chemical changes. The ultimate utilisation of the extra amount of energy in an excited molecule may take place in several ways. The molecule has a greater chance than an unexcited molecule of acquiring sufficient extra energy to bring about its decomposition by collision with molecules possessing more than the average kinetic energy. The excited molecule is more likely to decompose. If it is not decomposed, the excited molecule may dispose of its energy either all at once or in stages. It may dispose of it as light of the same or lower frequency—that is, it may fluoresce. It may pass on its energy to another molecule with which it comes in contact, either decomposing it outright, or lifting its energy above the decomposition minimum, or ionising it. Or some or all of the absorbed energy may be used up in increasing the kinetic energy of translation of the molecule, and this will be manifested not by chemical change but by a rise in temperature. Since the electron arrangement of an excited molecule is different, its chemical behaviour may be quite different from the unexcited form.

Now the region of 3600–4000 Å, where the vat yellows and oranges absorb strongly, is beyond the visible violet rays, and therefore the quantum size of the light energy is large and the light may be expected to cause chemical change. The absorption of the vat blues and greens is in the region of orange and yellow, where the quantum size is much smaller, and for this reason they have, in distinction from the yellows and oranges, little chemical activity.

All the vat yellows and oranges do not absorb to the same extent in this active ultra-violet part of the spectrum. An attempt has been made by Scholefield and Goodyear to correlate the extent of destructive action with the completeness of absorption in this part of the spectrum, for individual dyestuffs.

The copper number of the same cotton dyed with different vat dyestuffs, and exposed to the fadometer for a standard period was used as a criterion of the extent of chemical destruction.

Dyestuff	Copper Number	Opacity to active light
Indanthrene Yellow 3GF	·78	·47
2GK	1·00	·34
Alizaranthrene Yellow 6R	1·07	·60
Duranthrene Gold Orange 2RT	1·10	·57
Indanthrene Yellow G	1·12	·59
Hydron Yellow 2G	5·0	·88
Anthra Yellow GC	5·52	·81
Cibanone Yellow R	11·1	1·09

The destruction of the blue component in mixed dyeings can also be explained by the ideas given above. The yellow molecules, absorbing an ultra-violet quantum, will be excited and when they come into contact with a blue molecule (which absorbs yellow and red) they will tend to give up their energy to it. They will either decompose it or excite it, so that in any case the number of excited yellow molecules will decrease and the number of excited blue molecules proportionately increase, and the blue molecules will be more likely to be decomposed. Whilst it would be easy for a yellow molecule, which absorbs a large quantum to excite a blue molecule, it would not be easy for a blue or green molecule (which absorb much smaller quanta) to supply sufficient energy to excite a yellow molecule. In this way there will be a decreased fastness to light on the part of the blue molecules, and an increase in the light fastness of the yellow molecules, as compared with their respective fastnesses when dyed alone.

There is other experimental evidence which gives support to the significance of this absorption by yellow and orange dyeings in the near ultra-violet. One of the newer vat oranges (Indanthrene Brilliant Orange GR) is claimed by the makers to be non-tendering. It has been examined, and appears to be inactive

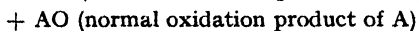
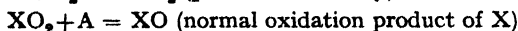
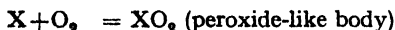
both in respect to tendering on illumination and to fading of blues and greens in mixed dyeings. It is significant that this dyestuff is also peculiar, having a negligible absorption in the region 3600–4000 Å. Scholefield and Goodyear⁶ also showed that when cotton cloth was dyed with Ciba Blue 2B and then saturated with R. salt, a measurable increase in the rate of fading by light took place. R. salt, sodium β -naphthol sulphonate, whilst colourless, absorbs strongly in the long ultra-violet region up to a wave-length of 3650 Å, and therefore agrees with the yellow vat dyestuffs in absorption in the active range. Preston and D. P. Milburn¹⁷ have been able to observe photometrically the course of fading of a blue dyestuff (Ciba Blue 2B) in presence of an active yellow (Anthra Yellow GC). These dyestuffs were dissolved together in a suitable solvent and were illuminated along one axis, and the depth of colour measured simultaneously along an axis at right angles. If the Anthra Yellow molecules behaved in the way described above, taking in quanta of light in the ultra-violet and passing them on to the blue molecules which were thereby decomposed, it might be expected that the rate of decomposition of the Ciba Blue would be approximately constant and proportional to the concentration of the Anthra Yellow, so long as there were sufficient Ciba Blue molecules to accept all the quanta that the Anthra Yellow molecules were able to absorb and pass on. When, by reason of the destruction by light, the concentration of Ciba Blue molecules fell below this concentration, then some of the active light quanta would not be available for destroying the Ciba Blue, and so the rate of decomposition would become progressively less. Such behaviour was in fact observed experimentally, complicated by the disturbing influence of the decomposition product of the Ciba Blue itself. This product was yellow and appeared to accelerate the destruction of Ciba Blue, which tended therefore to be destroyed with increasing rapidity as the decomposition product accumulated.

All these results make it probable that the primary reason for the activity of these yellow and orange vat dyestuffs, is their common ability to absorb light in the near ultra-violet. But there remains now an explanation of the manner in which the energy thus taken up works in bringing about the specific actions of fading and tendering.

In so far as the tendering of cellulose is concerned, all the evidence shows that the properties of the cellulose modified by the combined action of light and active dyestuff are similar to the properties of cellulose which has been modified by the action of oxidising agents. In the original paper, Scholefield and Patel¹ showed that the tendering of the cellulose was accompanied by an increase of the copper number and by an increase in the absorption of Methylene Blue, and these two facts together point to the tendering being due to oxidation. The oxygen required must come either from the air, or be furnished by the reduction of the vat dyestuff.

The simplest explanation of the accelerating action of the vat dyestuffs, then, is that they, by absorbing large quanta of light energy in the near ultra-violet, are able to supply energy for exciting the cellulose and making it more ready to react with atmospheric oxygen. There is, however, a large amount of evidence which points very strongly towards the conclusion that the vat dyestuff actually takes part in the reactions leading up to tendering, that it does so by a preliminary reduction to the leuco compound, and that this formation of the leuco-compound may contribute to the oxidation of the cellulose by two different mechanisms. The first, which will accompany the production of the leuco compound by light, will be an oxidation of the cellulose in amount chemically equivalent to the reduction of the dyestuff to leuco dyestuff. The second action will accompany the re-oxidation of the leuco compound by atmospheric oxygen. There is much evidence to show that the re-oxidation of an active reducing agent, either by air or by other oxidising agents, does not stop at the normal stable oxidation product but goes further with the production of highly oxidised

products which are themselves powerful oxidising agents^{19, 20} (see *Chem. Soc. Ann. Reports*, 22, 117, 1925, for a summary of evidence drawn from experimental observations upon different classes of organic compounds). These substances may be relatively stable if kept in the dark, and behave like organic peroxides. The hypothesis is stated in its simplest terms by Engler⁵ as follows—A re-oxidation of a substance "X" (in our case leuco dyestuff) in the presence of a substance "A" which is capable of being oxidised (such as cellulose or Ciba Blue 2B), may bring about the oxidation of "A" in the following way—



It is highly probable that both the simultaneous leuco compound-oxycellulose formation first mentioned and the attack upon the cellulose during re-oxidation of the leuco compound both take place, and we have not, at the moment, any means for distinguishing the relative extents to which they have operated in any given case of fading or tendering. So far, the strict experimental demonstration of tendering or fading action due to the primary simultaneous reduction of the dyestuff and oxidation of the cellulose alone has not been made owing to the necessity of carrying out the exposure, and subsequently examining the dyed sample for tendering, oxycellulose formation, etc., under conditions such that air is absolutely excluded, since if once air is allowed access, re-oxidation of the leuco compound will also take place. The peroxide formation mentioned above may occur and seriously obscure the direct evidence of the primary action. Both of the suggested mechanisms depend upon the initial formation of the leuco compound by the action of light, and there is some evidence of its formation upon exposure of some of the active dyestuffs.^{6, 18} It is not to be expected that the leuco compound will be visibly formed in every case, since there must be re-oxidation of this compound by the air, so that the amount of leuco compound visible will depend upon the relative rates of formation and re-oxidation. Scholefield and Goodyear⁶ have shown that dyeings of Cibanone Orange R, Cibanone Yellow R, Hydron Yellow GG and Anthra Yellow GC change colour on illumination in the direction of the colour of the free leuco compound and that the original colour is restored if the material is allowed to stand in the dark in contact with moist air, or, more rapidly, if the material is wetted. They also tried to demonstrate the formation of the leuco compound by a reaction which has since been utilised for dyestuff manufacture and in printing processes. The reduced vat dyestuffs are phenolic in character and may be expected to couple with diazotised bases to form azo-derivatives. By choosing a suitable base, the resulting compound should give a distinctively coloured stable compound which should be distinguishable from the dyestuff itself and from any non-leuco product that may be formed. It was found that such a coupling took place when the chemically formed leuco compounds were treated with diazotised Variamine Blue B base, giving distinctive colourations. When dyeings which had been exposed to light were treated with the base, colours similar to those produced with the chemically formed leuco compound were obtained with Caledon Yellow GS, Anthra Yellow GC, Duranthrene Gold Orange Y and its derivative Caledon Gold Orange RRT. The results of a large number of experiments in which dyeings were exposed in glass tubes either exhausted or filled with inert gasses, are difficult to interpret. Recently, R. Sadasivan has examined the effect of illumination when suspensions of the dyestuffs in a number of liquids, particularly pure dry ethyl alcohol, were illuminated in sealed tubes in the absence of air. Here the alcohol may serve as a reasonable chemical analogue for cellulose.²² After illumination, many of the dyestuffs showed a change in colour (*e.g.*, Cibanone Orange R, Anthra Yellow GC, Duranthrene Gold Orange Y, Indanthrene Yellow 3R) always in the direction of the colour of the leuco compound. After exposure the alcohol was

immediately removed and tested for aldehyde which was estimated colorimetrically, using a sensitive Schiff's reagent, with the following results—

Dyestuff					Aldehyde formed
Cibonone Orange R	...	...	...	...	100
Anthra Yellow GC	...	...	...	...	40
Duranthrene Gold Orange Y	...	...	...	...	25
Indanthrene Yellow 3R	...	...	...	...	12
„ Yellow G	...	...	...	...	·08
„ Brilliant Orange GR	...	...	...	...	·04
Indigo	...	...	...	...	·00
Without dyestuff	...	...	...	...	·00

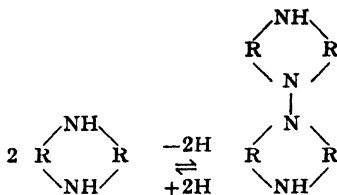
It will be seen that these dyestuffs are active in producing aldehyde from alcohol in the same order as they are active in producing oxycellulose from cotton. On full exposure to air, the colour of the suspension returns to that of the normal dyestuff. We have in these experiments a justification for the oxidation-reduction hypothesis.

Since we have assumed the necessity for the formation of the leuco compound under the action of light as a condition of the destructive changes, it is possible that the activity of a dyestuff besides depending on the degree of absorption in the active ultra-violet region, will also depend upon the ease with which the dyestuff can be reduced, that is to say, essentially upon its reduction potential. Preston and Milburn¹⁷ have examined this point in some detail. By dyeing cotton from baths containing a mixture of two dyestuffs in the presence of insufficient hydrosulphite to reduce both of them, and noting which of the two dyestuffs was taken up in the greater proportion, it has been possible to group the dyestuffs roughly in order of their ease of reduction. Special experimental procedure had to be worked out to ensure uniformity of particle size of the dyestuffs before vatting, and also to prevent preferential re-oxidation. The following dyestuffs are placed in decreasing order of ease of reduction—

Yellows	Blues
Caledon Yellow G	Ciba Blue 2B
Anthra Yellow GC	{ Caledon Blue RC
	{ Caledon Blue RS
	{ Caledon Blue GCD
{ Indanthrene Brilliant Orange GR	
{ Caledon Gold Orange Y	
Indanthrene Yellow 3R	Caledon Dark Blue BM

Attempts by these workers¹⁷ to measure the reduction potentials of the dyestuffs by potentiometric methods met with experimental difficulties of such magnitude that only slow progress could be made, and at present no general conclusion can be drawn from their results.

There is evidence in many directions that the oxidation, either by air or by oxidising agents, of the leuco compound, can simultaneously cause severe chemical attack of the cellulose,¹ fading and destruction of the blue component of mixed dyeings, formation of hydrogen peroxide,^{2, 4} and other reactions of an oxidising nature. One of the most striking examples of this is the behaviour of indanthrene (Caledon Blue RS). If cotton containing the reduced dyestuff as it comes from the dye bath is allowed to re-oxidise in air, the resulting colour is a flat greenish shade. A similar effect is also produced if a normal dyeing is treated with oxidising agents. The colour can be restored to the full blue shade of the dyestuff in each case by treatment with a mild reducing agent. The green shade is due to the formation of azhydrine compound in the dyestuff.



This demonstrates that the mere oxidation of the leuco body by air is sufficient to cause simultaneous oxidation of the dyestuff itself.⁹

Scholefield and Patel,¹ in their original paper, cite evidence to show that the re-oxidation of the reduced vat dyestuff can give rise to peroxide formation, and this is confirmed by Landolt,³ Haller and Ziersche,²⁰ and others. In many cases, since the illumination was carried out upon the dyeing saturated in water, or in aqueous solutions, or upon solutions or suspensions of the dyestuffs themselves, or else the dyeings were subsequently treated with aqueous solutions of the reagents used for detecting peroxides, the actual presence of hydrogen peroxide was observed. The formation of titratable quantities of hydrogen peroxide upon illumination has been demonstrated by Baur and Neuweiler¹⁰ for suspensions of zinc oxide, by Scholefield and Preston⁶ for suspensions of active yellow and orange vat dyestuffs, and by Landolt³ for cotton dyed with Cibacron Orange R. Since almost without exception, fading and tendering are greatly retarded by exposure of dyed samples in a thoroughly dry condition, it may be that hydrogen peroxide is normally formed and is requisite for the tendering and decolourising effects, or it may be that the dyestuff peroxide (as suggested by Gebhardt) is alone responsible. The distinction is not primarily important, the necessary condition according to our ideas being only the formation of active oxygen by the re-oxidation of the leuco compound. Strong evidence of the greater reactivity of the reduced dyestuff is given by Scholefield and Patel¹ who show that if dyeings of the active vat yellows and oranges are exposed to light in the reduced condition (*i.e.*, saturated with hydrosulphite and caustic soda solution), extensive tendering or decolourisation of an accompanying blue vat dyestuff take place in a very short time. These destructive effects do not occur if re-oxidation is allowed to take place in the dark. However, when re-oxidation is allowed to take place in the dark and then the dyeings are subsequently illuminated, tendering or decolourisation are again brought about. The tendering does not take place if the dark-oxidised dyeings are washed thoroughly before exposure to the light. After control experiments had shown that the caustic soda present was not responsible for the greater changes produced by illumination of the dark-oxidised unwashed dyeing, Scholefield and Patel came to the conclusion that the oxidation of the reduced dyestuff was accompanied by the formation of hydrogen peroxide upon the fibre, and that this in the presence of light was responsible for the oxidising action of the cellulose. They showed that orange and yellow dyeings of the material saturated with a very weak solution (·03%) of hydrogen peroxide were materially tendered, and an accompanying vat blue decolourised on illumination, whereas plain cloth under the same circumstances was scarcely affected. The experimental conditions were carefully re-examined by Scholefield and Goodyear,⁶ since Landolt¹¹ held that the effect was not necessarily due to the reduced condition of the dyestuff, but was brought about by the known oxidising action of air upon cellulose in the presence of caustic alkalis.⁷ However, Scholefield and Goodyear were able to affirm the greater activity of the leuco dyeings. They showed that the difference in chemical effect produced upon the reduced dyeing as compared with that upon the caustic-saturated, unreduced dyeing was more pronounced for short exposures to light. We should, of course, expect the action due to the leuco compound to be effective only during the relatively short period of re-oxidation.

The ability of certain of the vat dyestuffs to produce oxidation reactions in presence of atmospheric oxygen and under the action of light, is paralleled in many respects by the accelerating influence exercised by some of the vat dyestuffs upon the oxidation of cellulose by chemical oxidising agents. This is a point of considerable technical importance, since a large number of the vat dyestuffs are normally resistant to the action of hypochlorite solutions of ordinary bleaching strength, and are used very extensively for the dyeing of coloured threads to be woven with grey yarns into material which is then bleached in the piece. Again, the air oxidation of the vat dyestuff on cotton or viscose material, after leaving the dye bath, is not always practicable, and supplementary oxidising agents such as hypochlorite, perborate, bichromate, etc., are in common use for this purpose. Occasional severe tendering of vat dyed stripes in woven pieces is experienced after hypochlorite treatment, whilst the undyed portions are left intact. Scholefield and Patel² called attention to these facts, and showed (1) that the presence of certain vat dyestuffs, principally the vat yellows and oranges caused enhanced tendering of cotton and viscose by dilute solutions of hypochlorite, (2) this tendering action only took place on exposure to light, (3) dyeings which were active in producing tendering by light and air—*e.g.*, Cibacron Orange R, Cibacron Yellow R, Hydron Blue 2G, Anthra Yellow GC and Cibacron Yellow 3G—were also very active in causing tendering by light and hypochlorite, (4) the vat blues and greens showed little activity in causing tendering. Since then, other workers, including Whittaker,⁴ Nodder and Derrett-Smith,⁵ have taken up this question. Nodder and Derrett-Smith, using as their criterion of cellulose attack the Solubility Number, have shown that, among the dyestuffs they examined, vat yellows and oranges and, to some extent, reds and violets, brought about enhanced oxidation of the cellulose. Blues and greens were relatively inactive. Their experiments also show quite definitely that light is necessary for bringing about this increased oxidation, although the action of light does not materially increase the attack on undyed cloth by hypochlorites. When this effect of vat dyes in bringing about increased tendering of cotton by hypochlorites is compared with their effect in bringing about oxidation by air, there are thus two close similarities—(1) the necessity for illumination, (2) the restriction of the active dyestuffs to approximately the same colour group. We have, therefore, tried to see what experimental consequences might be expected from an application of the theory of fading and tendering by light and air, to the tendering of cotton by light and hypochlorites.

According to this theory, when cotton dyed with the active dyestuff is immersed in a hypochlorite solution it will absorb light in the near ultra-violet and become momentarily reduced to the leuco compound. The leuco compound will be re-oxidised as it is formed, with the production of the energetically oxidising intermediate compound, and this at the moment of its formation will be able to oxidise the cellulose by the linked oxidation already described.

If, for the time being, we confine the accelerating action of the light to the supposed production of leuco compound, we see why the blues and greens do not cause tendering. Having no absorption band in the near ultra-violet, they cannot by this theory take up light energy necessary for conversion to the leuco compound, and the formation of the leuco compound should be essential for destructive oxidation to take place.

An immediate consequence of these assumptions is that when dyeings upon cellulose are brought into the reduced condition in the dark and are, still with the exclusion of active light, treated with dilute hypochlorite solutions, they should suffer greater oxidising attack than fully oxidised vat dyeings when these are treated with hypochlorite solutions in the dark, under exactly similar conditions of pH, concentration of available chlorine and temperature. Moreover, this increased chemical attack may be expected to occur *without reference to the colour and absorption spectrum of the dyestuff*.

As this aspect of the problem does not appear to have been examined by other workers, we have begun an investigation of which the preliminary results are available. Cotton yarn carefully purified was dyed in the dark room with a number of vat dyestuffs. After dyeing it was washed thoroughly with water and allowed to oxidise in the air, still with the exclusion of light. Part of the dyed yarn was then treated in the dark with cold 2% hydrosulphite solution to which a small quantity (1%) of formalin was added to prevent the separation of sulphur. When reduction of the dyestuff to its free leuco compound was complete, the yarn was removed, rinsed rapidly in cold water, and completely submerged in a large quantity of hot water which had been kept at the boil for at least 30 minutes prior to the experiment to remove all dissolved air. After three changes of boiling, boiled-out water, the dyeing was washed in cold boiled-out water, wrung out, and immersed in sodium hypochlorite containing six grams of available chlorine per litre, buffered with Sørensen's phosphate buffer to a suitable pH . By this experimental procedure, we hoped to remove all impurities that might be expected to influence the rate of oxidation of the chemic, and to have finally only bleached cotton dyed with free leuco vat dyestuff. The control was performed with the dyed cotton in exactly the same way, omitting only the reducing treatment with hydrosulphite. Only lighting from a dark-room lamp had been allowed during the whole of the operations. After the chemic treatment, the yarn was washed thoroughly in water, allowed to dry in the dark, and the tensile strength determined on a Moscrop tester.

The following results were obtained; each result given is the mean of 150 single thread strength determinations—

Dyestuff	% Loss in strength due to dyeing	% Loss in strength of fully oxidised dyeing on treatment with hypochlorite		% Loss in strength of reduced dyeing on treatment with hypochlorite		Increased loss in strength due to reduction before hypochlorite treatment	
		pH 6	pH 8	pH 6	pH 8	pH 6	pH 8
White Yarn ...	*2.5	30.0	16.4	†30.0	†15.6	0.0	—0.8
Caledon Blue RC ...	2.8	23.8	15.6	38.5	28.8	14.7	13.2
Caledon Jade Green ...	1.9	30.0	21.5	35.5	21.5	5.5	0.0
Caledon Blue RS ...	2.3	36.5	18.5	37.2	17.3	0.7	—1.2
Caledon Yellow G ...	4.5	28.9	13.5	37.5	20.8	8.6	7.3
Indanthrene Brilliant Orange GR ...	0.0	28.4	13.3	37.8	22.4	9.4	9.1
Indanthrene Bordeaux B ...	3.3	41.6	21.6	49.4	32.2	7.8	10.6
Cibacron Yellow R ...	0.4	36.7	22.3	46.4	37.5	9.7	15.2
Cibacron Orange R ...	0.8	35.3	19.6	53.8	40.0	18.5	21.4
Anthra Yellow GC ...	—1.5	41.0	21.8	57.8	40.0	16.8	18.2

It will be seen that, with the exception of Indanthrene (Caledon Blue RS) there is a fairly consistent increased loss in strength in all the dyeings as the result of reduction treatment before the oxidation with hypochlorite. The conditions of treatment with hypochlorite were not, perhaps, the best that could have been chosen for demonstrating the accelerating effect due to the leuco compound since a fairly severe and prolonged treatment was given—(even the white yarn has suffered marked degradation). We should expect any effect due to the re-oxidation of the leuco compound to bring about its specific effect in a relatively short time. Experiments taking this into account, using hypochlorite containing three grams of available chlorine per litre and allowing the hypochlorite to act for a total period of 15 minutes only, gave the following results:—

*This yarn was treated with caustic and hydrosulphite solution of the same concentrations and at the same temperature as the baths from which the vat dyestuffs were dyed.

†The white yarn was given the same reducing treatment as was employed for the dyed yarns.

Dyestuff	% Loss in strength due to dyeing	% Loss in strength of fully oxidised dyeing on treatment with hypochlorite		% Loss in strength of reduced dyeing on treatment with hypochlorite		Increased loss in strength due to reduction before hypochlorite treatment	
		<i>pH</i> 6	<i>pH</i> 8	<i>pH</i> 6	<i>pH</i> 8	<i>pH</i> 6	<i>pH</i> 8
White Yarn ...	* -6.2	-2.6	-2.6	† -2.2	† -2.6	0.4	0.0
Caledon Blue RC ...	-9.0	7.3	8.0	19.7	12.8	12.4	4.8
Caledon Jade Green ...	0.7	4.8	2.9	8.8	5.1	4.0	2.2
Caledon Blue RS ...	-3.6	2.6	4.4	9.9	6.6	7.3	2.2
Caledon Yellow G ...	-9.1	19.4	15.7	40.2	25.3	20.8	9.6
Indanthrene Brilliant Orange GR ...	-10.6	-2.6	-3.6	5.5	-0.8	8.1	2.8
Indanthrene Bordeaux B ...	-2.6	12.4	4.4	32.5	13.9	20.1	9.5
Cibanone Yellow R ...	1.4	13.1	9.5	41.6	29.8	28.5	20.3
Cibanone Orange R ...	-3.6	14.2	15.0	48.2	26.6	34.0	11.6
Anthra Yellow GC ...	-8.0	10.2	6.5	31.3	26.6	20.1	20.1

Besides producing enhanced chemical attack of the cellulose the effect of the leuco compound in intensifying the oxidising action of the hypochlorite is shown by the greater colour changes produced in some of the dyestuffs when the dyeings are immersed in the chemic in their leuco state. For instance the oxidised dyeing of Caledon Yellow G is scarcely affected by the hypochlorite, while the leuco dyeing is changed to a flat greenish-yellow. Cibanone Yellow R and Anthra Yellow GC show the same effect to a less marked extent. The behaviour of Indanthrene (Caledon Blue RS) is interesting. This dyestuff is changed by the hypochlorite to a flat greenish colour and the amount of colour change both with dyeing and with reduced dyeing is very considerable, particularly at *pH* 6. Unlike the other dyestuffs, this change is reversible, and the original blue colour is restored by hydrosulphite. Evidently the very easily oxidised Indanthrene is changed to the azhydrin compound already mentioned. The point is that Indanthrene appears to have suffered a much more complete attack than any of the other dyestuffs and this may be the reason for the mild attack upon the cellulose.

It may be possible to interpret the increased oxidation effect due to the leuco compound in a rather different manner following an observation made by Kauffmann,¹² who found that the oxidising effect of hypochlorite solutions is very considerably enhanced by the presence of traces of hydrogen peroxide. In his original paper he shows that the destruction of the colour of an easily oxidisable dyestuff (Orange II) by sodium hypochlorite, which, under specific conditions of dyestuff and hypochlorite concentration, *pH* and temperature, requires 15 minutes, is completed in as many seconds when a small quantity (0.3%) of hydrogen peroxide is added. The hydrogen peroxide alone in the concentration used has practically no destructive effect. We have confirmed this, using Chlorazol Fast Scarlet 4BAS as the indicator dyestuff and have been able to show by colorimetric methods that the effect is operative over the *pH* range from 4 to 10. Kauffmann has shown that the accelerating effect can also be produced, though to a less extent, by other substances capable of being oxidised by hypochlorite, for instance, ammonia, urea, oxamide, etc. We may take this as evidence that, if during the re-oxidation of the leuco compound with hypochlorite an actual formation of hydrogen peroxide occurs, the oxidising action of the hypochlorite will be enhanced thereby and, instead of the increased rate of decolorisation of Orange II as in Kauffmann's experiment, there will be an increased attack on the cellulose. On the other hand, we may take the Kauffmann experiments as particular examples of the general idea of Engler, that when oxidation of a reduced substance takes place there may be powerful, concurrent oxidation of a second substance which is present.

(* † See Footnotes on page opposite)

We have tried the effect of adding cloth dyed with certain of the active vat dyestuffs to mixtures of Orange II with hypochlorite and in the case of Duranthrene Gold Orange Y and Caledon Yellow G we appear to have evidence that a slight but consistent increase in the rate of decolorisation is caused by a dyeing that has been exposed in the fadeometer as compared with an unexposed dyeing. In comparing the effect of cotton dyed on the one hand with the fully oxidised dyestuff and on the other with the free leuco compound, we have not been able to get sufficiently marked and consistent results, to come to any conclusion. The differences in time of the decolorisation are, at best only very small, since even with heavily dyed cotton only a relatively small proportion of dyestuff can be brought into a given volume of hypochlorite. We are endeavouring to improve the method of carrying out these experiments with the object of getting more definite and consistent results.

We have considered at length the oxidation of the cellulose by light and air under the influence of the active vat yellows and oranges. No less interesting is the enhanced accelerated fading of a non-active dye such as a vat blue or green when it is dyed along with a vat yellow or orange. The non-active dyestuff may be a member of the vat series and may, when dyed alone, have very high resistance to light action, or it may be a direct, sulphur, or basic colour and may therefore have any degree of light fastness from very good to poor, but in almost every case the dyeing together with one of the vat yellows and oranges causes a marked increase in fugitiveness. At the same time the light fastness of the yellow dyestuff of the combination is usually correspondingly increased. It has been shown that this behaviour is to be expected if the assumptions made during the application of the Quantum Theory to the general problem are valid. In considering what reactions are likely to take part in this fading of the non-active dyestuff, it is inevitable that we should first examine its behaviour in the light of the knowledge that we have obtained from the study of the degradation of cellulose, since the antecedent conditions of light, air, moisture and the presence of an active vat yellow or orange are the same in both cases. Before we can draw a satisfactory parallel between the decolorisation of the non-active dyestuff and the formation of oxycellulose we must know whether the decolorisation is indeed due to oxidation, and not to reduction, association, condensation or other cause. The experimental treatment of this part of the question has been rather meagre and has only dealt with isolated dyestuffs largely because of the great experimental difficulty of separating and identifying the transformation products of the faded dyestuff. E. Hibbert¹ has shown that indigo-dyed fabric exposed to the light of the fadeometer arc gives a product which can be identified with isatin, and that this product is also obtained when the dyeing is treated with an oxidising agent such as permanganate. The destruction of a direct colour, *e.g.*, Chlorazol Sky Blue 1FF or Direct Blue 2B topped upon a dyeing of an active vat yellow or orange is prevented by the exclusion of air.^{4, 6} The fading of Direct Blue 2B in a mixed dyeing gives rise to a decomposition product which can be extracted from the fibre. This was examined spectroscopically by J. G. Evans and shown to correspond very closely to the product from the oxidation of the dyestuff in aqueous solutions by mild oxidising agents.⁶

There is therefore some justification for regarding the non-active blue dyestuff in these mixed dyeings as offering itself to oxidising attack as an alternative to the cellulose. The extent to which an oxidisable dyestuff of this kind may protect the cellulose from oxidation when illuminated in the presence of an active yellow dyestuff has not been accurately measured. Landolt¹² has recently brought forward evidence to show that when a dyeing is saturated with alkaline hydrosulphite and exposed to light it will suffer extensive tendering and little decolorisation if the dyestuff is not readily oxidised but that if the dyestuff is easily oxidised (as with many of the indigoid dyestuffs) there will be little tendering but much decolorisation.

When a non-active dyestuff is considered as replacing the cellulose as an oxidisable substance there are certain properties of the dyestuff, not found in cellulose, which prevent us from applying, without modification, the fairly direct conceptions which we put forward to explain the behaviour of cellulose. If the non-active dyestuff is a vat dyestuff it may be indanthrene and possess the property peculiar to itself and its immediate derivatives of being readily and reversibly oxidised.⁹ A vat dyestuff moreover, unlike cellulose, is capable of being readily and reversibly reduced to its leuco compound. When it is reduced it will usually have a very different colour, it may absorb in the near ultra-violet and thus become temporarily an active dyestuff capable of causing self-destruction or tendering of the fibre. There is also the important question of whether a dyestuff in the leuco form is intrinsically less resistant to chemical attack. This is difficult to decide because the presence of the dyestuff in the leuco state has as a necessary consequence the coincident strong oxidising action as soon as air has access and commences to convert the leuco compound into the normal dyestuff. For instance, when Landolt^{13, 15} reports that the leuco compounds of many of the indigoid dyestuffs are susceptible to decomposition when exposed to air in the alkaline reduced form, it may not mean that the leuco compound is easier to oxidise destructively than the unreduced dyestuff, but that during the re-oxidation of the leuco compound by air, oxygen is available in an abnormally potent condition. It is now easier to understand why these destructive effects, which have been ascribed by Landolt and others to the greater instability of the leuco compound, always take place more readily in alkaline solution since it is well known that the re-oxidation of the leuco compound takes place with much greater rapidity in an alkaline medium (the leuco compounds of many of the vat dyestuffs, particularly of Caledon Yellow G, show considerable resistance to re-oxidation if prepared free from alkali) and this must make for a more vigorous coincident oxidation. Up to the present we have, for the sake of simplicity, considered the absorption of light only as causing primary reduction of the dyestuff to its leuco compound, but this does not necessarily mean that light plays no other part, either in the re-oxidation of the leuco compound, or the coincident oxidation whereby cellulose is degraded or a non-active dyestuff is decolourised. Many of the leuco compounds have, as has been noted, an entirely different colour from the original dyestuff, and the leuco compound of a non-active dyestuff may be capable of absorbing light in the active range. The experimental determination of the absorption spectra of the leuco compounds should be of great assistance in clearing up a large part of this question of enhanced reactivity of the leuco compounds under the action of light. Landolt has shown that Ciba Blue 2B is more sensitive when exposed in its leuco-state, being transformed partially to indigo and partially to a colourless compound. Milburn, as has been mentioned previously, has shown that the fading compound of Ciba Blue 2B accelerates the light destruction of the dyestuff. With these extra possibilities in mind, the hypothetical mechanism by which say, Ciba Blue 2B is faded in a mixed dyeing with Anthra Yellow GC becomes correspondingly complex, and while much, in an enumeration of the possible actions which may take place, must be pure speculation, there appears to be a reasonable chance of being able to examine experimentally some of the actions which our general theory will logically predict. Taking the Ciba Blue 2B and Anthra Yellow GC dyeing as an example it will be interesting to set out what might reasonably be expected to occur, and to see how far this is verified by the actual behaviour of the dyeing.

When the dyeing is illuminated there will be first the absorption of active light by the Anthra Yellow which will be reduced to the leuco compound. There must be a corresponding oxidation, either of the cellulose or of the Ciba Blue, or both may be oxidised to some extent. Then the leuco-Anthra Yellow may be oxidised by air to the dyestuff bringing about the coincident oxidation of the Ciba Blue 2B or of the cellulose. Alternatively the leuco-Anthra Yellow may,

instead of undergoing air oxidation, be oxidised by the Ciba Blue 2B which will be transformed to the leuco compound. This leuco-Ciba Blue 2B may on air oxidation act in the same way as the leuco compounds of the other vat dyestuffs and bring about coincident oxidation of Ciba Blue 2B or leuco-Ciba Blue 2B molecules, with a consequent permanent decolorisation, or there may be also an attack of the cellulose.

But Landolt¹¹, Scholefield and Goodyear,⁶ and Weber¹⁴ have shown that the leuco compounds of many of the halogenated vat dyestuffs, may, under the action of light suffer a dehalogenation. For instance, Gold Orange G is formed from the leuco compound of its chloro derivative Gold Orange RRT, and Landolt has shown that leuco-Ciba Blue 2B is transformed on exposure to indigo by the removal of bromine. Therefore we have the further possibility that the leuco-Ciba Blue 2B is debrominated to indigo as a preliminary to its destruction by oxidation to isatin. It should be possible to demonstrate the actual existence of Ciba Blue leuco compound or Anthra Yellow leuco compound and so eliminate some of these alternatives by the coupling with a diazotised base which would give a distinctive colour with Ciba Blue 2B leuco compound and a different colour with leuco-Anthra Yellow GC. Since the choice of bases for coupling has of late increased considerably, a suitable combination may soon be found.

According to our general hypothesis this fading and oxidising action peculiar to the vat yellows as a class depends upon the possession of the properties of absorbing light of short wave-length, of being reversibly reduced in such a way that re-oxidation to the normal compound is reasonably rapid, and of resisting oxidation. It is evident that other dyestuffs may resemble the vat yellows in possessing these properties in varying degrees, consequently, the general conception of tendering and fading may apply in some measure to dyestuffs of other classes. There is already evidence available to bring sulphur and basic²¹ and possibly certain direct dyestuffs within the generalisation.

In this paper an attempt has been made to establish a hypothesis which shall be capable of explaining comprehensively and consistently the experimental results obtained in the study of the remarkable behaviours of vat dyestuffs on cotton. It will be seen that the problems raised are complicated by the number of different ways in which chemical change can proceed, and, added to this are the great difficulties which attend a satisfactory experimental treatment. We are encouraged in putting forward our ideas by the hope that they may be a help to other workers in elucidating some of the many remarkable phenomena which are initiated or stimulated by light.

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DISCUSSION

Mr. W. Harrison stated that from numerous experiments carried out by him in 1912 or thereabouts it appeared that cellulose was acted on by light in the absence of dyestuffs. In air, the cellulose was acted on with the formation of carbon dioxide, soluble bodies having reducing properties to Fehlings solution, and a material having most of the properties of so-called oxycellulose. It was interesting to note that even in a vacuum, light caused a similar decomposition but to a lesser extent. As a rule light caused a dyestuff to be reduced and the cellulose oxidised but it was noticed at that time that in the re-oxidation of a dyestuff, reduced by cellulose under the influence of light, the original colour was not always reproduced. In that paper it was also shown that some dyestuffs faded in absence of fibre, no doubt by air oxidation, although the direct destruction of the dyestuff must not be overlooked. Cases were described where colour was destroyed by light causing interaction of groupings in different parts of the dyestuff molecules. It is only to be expected that light would bring about complicated reactions such as were described in Scholefield's paper.

Whilst it admitted that organic peroxides exist and that it was not impossible that light may cause the formation of peroxides from oxygen and water or organic compounds there was, at present, no incontrovertible evidence that the tendering effect of light on cellulose dyed with yellow and orange vat colours is due to the action of a peroxide. There was no need to assume this, light acts directly on cellulose to form materials such as oxycellulose and also to produce tendering and it only needed an acceptor to take up the products of the reaction in order to accelerate the tendering. One need only quote the effect of gelatine on the photographic plate and refer to the valuable work of Kodak in ascertaining the nature of the acceptor present in gelatine. The effect of hypochlorite on leuco vat dyes in the dark was of considerable interest as showing possible catalytic action but it does not prove any peroxide formation and may in fact have no connection with the effects produced by light. From the practical point of view one wished to learn which dyestuffs were safe for dyeing cellulose and if possible how to prevent the tendering action of the unsafe dyestuffs.

Mr. Turner said that a reference to the bibliography of their paper would show that they were aware of the earlier work of Mr. Harrison, Gebhardt, and others. He did not think, however, that these authors had, at the time, exactly the same explanations in mind as the ones that were now put forward, nor had they then in front of them such evidence as was available later. Mr. Harrison would see from the paper that they were aware of the action of light on undyed cellulose in producing degradation products, but the action of light in the presence of the active dyestuffs causes much more rapid and thorough degradation. That was the effect they were investigating. With regard to the statement by Mr. Harrison that they need not assume the formation of peroxide, and that cellulose and oxygen might interact directly in the presence of light, this was quite true and had not been excluded. On the other hand, if the conditions for the utilisation of light energy were satisfied this did not exclude an explanation based on the formation of intermediate chemical products. Where they had the formation of hydrogen peroxide on illumination of the dyeings under certain conditions—a fact which appeared to be fully substantiated—they had to take this into account in their explanation. A great deal of the confusion about the actual formation of hydrogen peroxide or peroxide bodies arose from the lack of reagents which would show their presence specifically. Ferric ferricyanide appeared to react with certain dyestuffs under conditions where one could not easily imagine the presence of reducing products. Potassium iodide solution could not necessarily distinguish between hydrogen peroxide as such and organic peroxides. They did not exclude absolutely the influence of the chemical structure of the dyestuff. Mr. Harrison would see that in the table of results that they had given showing the action of hypochlorite upon the reduced vat dyeings, the dyes which were

very active photochemically such as Cibacron Orange R or Anthra Yellow GC, still caused most degradation, although light had been excluded throughout. Moreover he would see that the action of hypochlorite at pH 6 was in general much more vigorous than at pH 8. This influence of pH did not correspond to the effect when undyed cellulose was treated with hypochlorite where they had a maximum attack at pH 7. The leuco dyestuff at pH 6 would be in the free-acid form and at pH 8 in the salt form and this might have some influence on the accelerating effect of the dyestuff. They had also observed the formation of bubbles of a gas when the leuco dyeing was placed on the hypochlorite. This effect was not observed with the fully oxidised dyeing. They hoped to be able to identify this gas, and if it happened to be oxygen, it would give support to the mechanism based on the Kaufmann reaction that they had suggested in the paper. They admitted that many of the ideas they had put forward were speculative, but they thought that the informality of a conference justified them being put forward without rigid experimental proof. They felt, as he had said before, that a fairly connected explanation such as he hoped they had given would prove suggestive of new ideas to other workers.

Mr. W. Kershaw, asked whether the authors had been in touch with Dr. Robert Robertson. During the war he had established the presence of some peroxide substances in anæsthetic ether. The speaker believed that alcohol was always present in ordinary ether and this might be the source of the objectionable impurities formed when ether was exposed to light action.

In reply, Mr. Turner said that the formation of unsaturated highly oxidised substances when ether was exposed to light now appeared to be well established.

Mr. J. G. Williams said that this question of the rapid tendering of rayon furnishing fabrics was a very serious one and he had examined a number of cases where fabrics had broken down in the first wash after only a few months of use. When he first encountered these complaints he had attributed the fraying of the fibres and the breaking of the yarns to some excessive rubbing in the washing process. Complaints have been getting more and more common and now retail buyers were doing all they could to discourage the sale of fadeless rayon furnishing fabrics because they were so unsatisfactory in this tendering. For some years now he had reported in such cases that the existence of vat dyes which caused this tendering was known and that dyers using such dyes were not producing satisfactory merchandise. It was obviously essential that a range of safe dyes should be found and used. He had noted that the rayon was apparently much more rapidly attacked than the cotton in a fabric, for when the rayon threads had no strength at all the cotton was still of fair strength.

Mr. Turner referred Mr. Williams to the paper by Mr. C. M. Whittaker recently read before the Society of Dyers and Colourists where this question had been treated in some detail.

Mr. A. E. Delph said that lists of safe vat dyes had been published but of course without guarantee. Experiments had been made, which he described briefly, with sunlight and ultra-violet light as the agents in tendering. They had found that the tendering produced in a vat dyeing by treatment with dilute hypochlorite under specified conditions was some guide to the destructive action produced by the dyestuff on the fibre when submitted to the action of light alone.

Mr. Turner said that the main difference in the accelerating action of vat dyestuffs upon the destruction of cellulose by light and in the presence of hypochlorite respectively appeared to be that in the presence of hypochlorite, more dyestuffs were active. These extra members of the active group were mostly reds, bordeaux, etc. Here he thought they might suspect an influence due to the chemical constitution since many of these dyes had a destructive structure in which a number of anthraquinone groups were connected one to another by di-imide rings.

THE ABSORPTION OF DIRECT DYESTUFFS BY CELLULOSE

Some Notes on Current Research

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Chairman MR. W. P. WALKER

The Estimation of Dyestuff absorbed

Whilst many attempts have been made by scientific workers to determine accurately the absorption of dyestuffs on cellulose materials, this problem has only recently been solved in a satisfactory manner. Quantitative chemical methods, such as determination with titanous chloride, for example, have been put forward, but have proved unsuitable for routine purposes. The most serious obstacle to the use of chemical methods lies in the fact that on dyed materials the proportion of colour to substrate is as a rule small, so that large amounts of the latter are required for each estimation. A suitable micro-chemical technique might overcome this difficulty, but no such technique has yet been found.

The alternative lies in physical or colorimetric methods. The direct determination by optical means of the colour content of a textile material would be the ideal, but the difficulties here are obvious and probably insurmountable. The solution to the problem has been found in the discovery that certain solvents will strip the dyestuff quantitatively without destroying its colour. A mixture of pyridine and water is a most effective and convenient stripping agent for direct cotton colours.

Once the dye has been removed its estimation in the solution is readily effected by means of a good modern colorimeter of the Duboscq type, in which the unknown solution is matched against a standard solution of the pure dyestuff by altering the depths of the respective liquid columns. The accuracy attained, when the precautions usual in colorimetry have been observed, depends largely on the good design of the instrument. We have found the Lertz colorimeter, simple Duboscq pattern, capable of estimating dyestuffs—with the exception of yellows—within 1%. For yellows a highly intense light source, followed by a dense filter passing violet light only, is necessary, but even under these favourable conditions the human eye fails to give an accurate result. The use of the potassium photo cell should overcome this difficulty in the estimation of yellow dyes, but this application is still in the experimental stage.

Exact Experimental Dyeing

In order to carry out exact measurements on dyestuff absorption, so as to arrive at a full understanding of the factors which influence the amount of colour absorbed, it is necessary to work out a technique not only for the accurate estimation of the latter, but also for the carrying out of the dyeing process under strictly controlled experimental conditions. To attain this end we have found it necessary to use chemically pure dyestuffs, prepared from the technical materials by repeated salting out with sodium acetate and alcohol. It has also been necessary to maintain a constant temperature within $0.2^{\circ}\text{C}.$; to guard against contamination from the vessels by the use of silver supports and resistance glass dyebaths, and to prevent evaporation by using mercury sealed ground-on condensers. In experiments on rate of absorption agitation of some kind is necessary. To avoid troublesome corrections it is generally desirable to use such a large ratio of liquor to material that the concentration of the dyebath is not seriously reduced by the absorption of colour. The colorimetric estimation of absorbed dye, which is quite feasible with only one-twentieth of a milligram available, makes possible the fulfilment of this last condition.

Using the method which has been outlined, we and our colleagues have made accurate measurements of the absorption of several selected colours. In order

to make possible a theoretical treatment of the rate of absorption, we have so far used the plane viscose sheet known as "Cellophane" in most of our work. We have studied the effect of the following factors on the amount of dyestuff absorbed—

- (1) Time of dyeing.
- (2) Thickness of cellulose sheet.
- (3) Concentration of added electrolytes (neutral salts).
- (4) Concentration of dyestuff.
- (5) Temperature.

Our tentative conclusions as to the effect of these will now be briefly discussed.

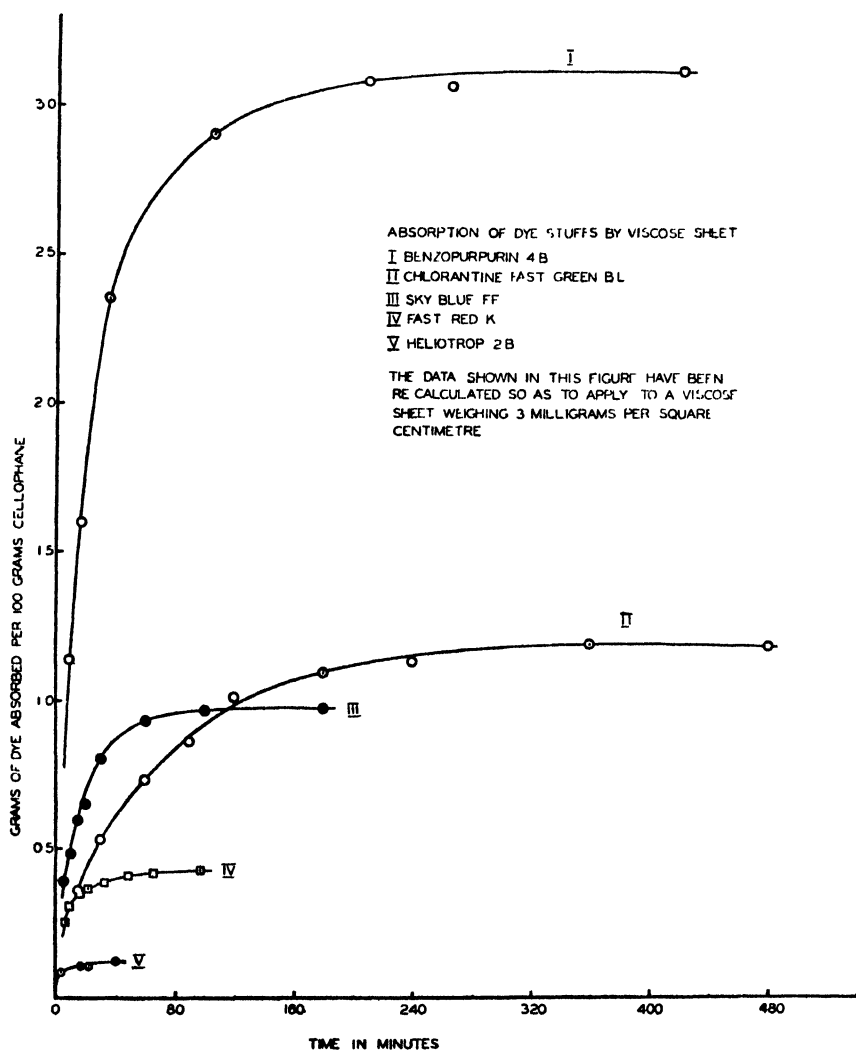


FIG I

(1) Time of Dyeing

Using cellulose sheet, and maintaining constant all other factors such as dyestuff concentration 0.05 g/l, salt concentration 5.0 g/l, and temperature 90 °C., the effect of time on the absorption of five typical direct colours is shown in Fig. 1. In each case the absorption of dyestuff is rapid at first and gradually slows down until a final equilibrium is reached. Mathematical analysis of the shape of each curve shows that the process of absorption is probably one of diffusion. This hypothesis is supported by the examination of cross-sections under the microscope. It is found that the outer surface of the sheet is immediately dyed, and that the colour then diffuses or spreads gradually until it is uniform across the section. This ultimate uniformity of distribution has been checked quantitatively by a delicate experiment in which the outer surfaces of a dyed sheet have been scraped off and their dye content compared with that of the interior. According to the diffusion theory, each absorption-time curve is characterised by (a) the final absorption value and (b) the time required for the absorption to reach any given fraction of the end value. A comparison of these times with those read off a standard curve calculated from diffusion theory gives a factor which, when multiplied by the square of the wet thickness of the cellulose sheet, is the apparent diffusion co-efficient of the dyestuff through the cellulose under investigation. A comparison made in this way of the absorption of certain direct dyestuffs is given in Table 1. (See also *J. Soc. Chem. Ind.* 1933, **52**, 88T).

Table I
The Absorption of Dyestuffs by Viscose Sheet at 90° C.

Dyestuff	Concentration of dye, 0.05 gm./litre.		Concentration of NaCl, 5.0 gm./litre.		Equilibrium Absorption gm. of Dye per 100 g. Cellulose	Mins for Half Saturation	Apparent Diffusion Coefficient cms ² /min. × 10 ⁸
	Weight of Cellulose Sheet milligrams per square centimetre						
Helotrope 2B ...	5.12	...	0.121	...	2.5	...	92.0
Fast Red K ...	5.58	...	0.42	...	6	...	30.4
Sky Blue FF ...	3.21	...	0.97	...	10	...	8.0
Benzopurpurin AB ...	2.92	...	3.1	...	15	...	4.6
Chlorantine Fast Green BL	3.01	...	1.20	...	40	...	1.73

The differences between the individual dyestuffs are very striking, and it will be noted that, except in the case of Chlorantine Green BL, a dyestuff of somewhat different structural type, the absorption value rises as the time for half saturation increases. Recent experiments show, however, that this correlation only holds good in a restricted sense, and it even appears that the order of the dyestuffs in such a table of properties may to some extent depend on the particular form of cellulose used. Quantitative measurements such as these nevertheless afford a tentative basis for a scientific classification of dyestuff properties. Those colours standing high in the table show poor affinity and washing fastness but high penetrating and levelling power, whilst those at the bottom of the table show practical characteristics at the other extreme.

(2) Thickness of Cellulose Sheet

Measurements made with Sky Blue FF on two thickness of cellulose sheet lead to almost the same value of the diffusion coefficient. This is a valuable confirmation of the diffusion hypothesis, according to which the time for half saturation is, *ceteris paribus*, proportional to the square of the thickness.

(3) Concentration of Added Electrolytes (Neutral Salts)

At the outset of our experimental work on Sky Blue 1F it was evident that this was a factor of the greatest importance. The outcome of a very large number of experiments on the effect of added electrolytes may be summarised very briefly as follows—

(a) Chemically pure dyestuffs are in general absorbed by cellulose to a quite negligible extent.

(b) The gradual addition of any neutral salt to the dyebath steadily increases the equilibrium absorption value.

(c) The apparent diffusion coefficient (the inverse of the half-saturation time) at first increases, reaches a maximum, and then decreases with increasing concentration of added salt.

(d) The relative effects of different salts are not in accord with the "Valency Rule" or any of the usual generalisations on the coagulation of colloids.

(4) Concentration of Dyestuff

If the concentration of added salt is maintained constant, the absorption at equilibrium rises steadily with increasing concentration of dyestuff in the solution, approximately in accordance with the equation—

$$D = kC^n$$

where D is the amount of dye absorbed, C the dyebath concentration, and k and n are constants. The value of n ranges between 0.3 and 0.7, the lower figure indicating that the absorption only increases very slowly with rising concentration of the dyestuff. It has been found that the absorption is, as regards dye concentration, a truly reversible one—there is no hysteresis as in the absorption of water by cellulose. The same final absorption value is reached if two samples, one undyed and the other previously dyed in a highly concentrated solution, are allowed to stand in the same dyebath.

(5) Temperature of Dyeing

The usual technical belief is to the effect that the absorption of different dyestuffs may be affected in opposite senses by temperature rise. Our experiments show that this is only true when dyeings are carried out for a constant short length of time. The effect of temperature rise is actually a two-fold one, the absorption at equilibrium is decreased, but the apparent diffusion coefficient or the rate of reaching equilibrium is increased. These effects are common to all the dyestuffs investigated, and are indeed very similar in amount. The equilibrium absorption is very roughly halved by 20° C. temperature rise, the apparent diffusion coefficient very roughly doubled by 10° C. rise.

The time allowed in technical dyeing is such that certain dyes, such as Heliotrope 2B and Fast Red K, are absorbed practically to equilibrium, so that in these cases the absorption decreases with rise of temperature. The absorption of colours such as Chlorantine Green BL is, however, in dyehouse practice far from equilibrium, so that if the temperature is raised its effect in increasing the diffusion or penetration rate predominates, with the result that a heavier shade is obtained at higher temperatures.

We would wish to emphasise the fact that a technique is now available for the ready and accurate estimation of small quantities of dyestuffs on cellulose materials. In this communication the problem of dyestuff absorption is treated from a physico-chemical viewpoint, making use of data obtained by the new technique. Partly on account of the wide field covered, partly because some of our results are not yet complete, the treatment in this paper is general rather than adequate. Full accounts of our work in various aspects are being prepared

for publication. One serious limitation from the textile point of view is that up to the present our work has for theoretical reasons been almost entirely confined to viscose sheet, though comprehensive experiments on other forms of cellulose are in hand.

Even at this stage, however, the application of our methods to the exact description of dyestuffs and dyed materials might usefully be considered. The following quantitative properties may be suggested for the characterisation of dyestuffs—

(1) "Affinity"—Amount of equilibrium absorption by a standard cellulose from a dyebath of standard concentration, salt content, and temperature.

(2) Levelling and penetrating power—Apparent diffusion coefficient in a standard cellulose sheet.

(3) Fastness to washing—Proportion of original amount (absorbed in test (1) above) remaining after a standard treatment with hot water or soap solution.

(4) Level dyeing on commercial viscose—Ratio of amounts absorbed in a standard test by two samples of specially prepared viscose of extreme properties.

Our thanks are due to our colleagues Messrs. W. M. Garvie, L. H. Griffiths, J. Hanson, and A. M. Patel, on the results of whose work this paper is largely based.

DISCUSSION

Mr. A. E. Delph, referring to the difference between the results obtained by the authors and those he and his colleagues had obtained, said that Messrs. Neale and Stringfellow were working with cellophane sheet whereas he had mainly confined his work to viscose yarn. He thought that with a further and fuller exchange of views a solution and an agreement might be reached.

Mr. Stringfellow asked Mr. Delph whether the differences in rate of absorption were due to the skin effect. He called attention to the fact that whereas Mr. Delph and his colleagues found the same saturation value for different kinds of cellulose, the work in Mr. Neale's laboratory pointed to the existence of different values. He would like to know whether this discrepancy could be attributed to the different conditions of experiment in the two cases. He also asked Mr. Delph what precautions had been taken to ensure standard conditions of agitation in the dyeing of viscose hanks: Mr. Hanson working with Mr. Neale had found the rate of dyeing to be greatly influenced by this factor.

In reply Mr. Delph said that he did not think the skin effect could be the sole cause.

Mr. W. Harrison suggested that the difference in the results obtained by Delph and others in dyeing rayons and by Neale in dyeing films depended largely on the time factor, it being expected that the films would take a much longer time to attain equilibrium.

In reply Mr. Stringfellow pointed out that in the work he had described, the effect of time had been very fully investigated and that the figures given for final absorption were true equilibrium values.

SOME OBSERVATIONS ON AGEING PROBLEMS

By H. B. BRIGGS, M.Sc., A.I.C.
(Imperial Chemical Industries Limited)

Chairman Professor A. F. BARKER

The problems which beset those in charge of ageing processes are many in number, and appear to vary in character from works to works to such an extent that it is very difficult to lay down the causes with any degree of certainty. Conflicting results are obtained in many cases, but all are agreed on one point, namely, that the process is one which requires constant care and supervision and one which is responsible for a big proportion of the jobs and allowances account.

Of the various styles, aged vat prints are probably the most erratic and it is these styles that are discussed in the present paper.

Ageing machines consist of three types—

- (1) The normal type usually referred to as the Mather & Platt, in which the cloth moves over rollers.
- (2) The festoon ager, in which the cloth hangs on festoons over rods which move forward.
- (3) The Indanthrene ager.

In the development of vat prints essentially two operations are concerned, although there are several sub-processes—(a) the reduction of the dyestuff to the alkali leuco-compound, and (b) the transfer of that body from the paste into the fibre; (a) must precede (b), but there can be no definite line of demarcation, for immediately the reduction of some of the dyestuff particles has occurred their fixation may commence simultaneously with the reduction of the other particles.

For process (a) the optimum condition for the reduction would be when the temperature is greater than 212° F. if it were necessary to consider only the interaction between the dyestuff and the reducing agent (formosul or its equivalents). Moisture is, however, necessary even for this portion of the development, and in cases where insufficient is present there is the probability that the dyestuff particles would become coated with a layer of leuco-compound which would prevent further action. This is of the greatest importance when dealing with those dyestuffs which are crystalline in character or whose leuco-compounds are of an especially insoluble nature.

For (b) it is generally agreed that a temperature as near as possible to the boiling point of water under the working conditions is desirable. In agers working at atmospheric pressures this will be slightly above 212° F., but in types such as the Indanthrene Ager a higher temperature is permissible.

It is thus seen that two different conditions are desirable for the work in hand, and, as both processes are going on simultaneously, one must be suffering at the expense of the other. Efforts are made to produce conditions favourable for (b), but rarely are they attained as the temperature almost invariably rises above the one desired.

When cloth printed with the normal vat printing paste—dyestuff, glycerine, potassium carbonate, formosul and thickening—enters the atmosphere of steam it rapidly absorbs moisture. The absorption of water regenerates the latent heat of vaporisation of water to steam, which raises the temperature of the fabric. The question as to whether heat is also generated by the reduction is less certain, and whilst some authorities state that this is the case others assert that the liberation of heat from this source is, at the most, only small.

Be this as it may, the heat generated rapidly raises the temperature of the steam and so creates a dry atmosphere which reduces the tendency of the fabric to absorb more moisture and retards or prevents fixation of the dyestuff.

The following table of saturation pressures of water vapour is of interest—

Temperature		lb. sq.	Saturation Pressure		Water Vapour		Relative Humidity percentage
° F.	° C.		in.	inches mercury	mm.	mm.	
212	100	...	14.7	29.9	760	...	100
216	102.2	...	15.9	32.4	822	...	92.5
220	104.4	...	17.2	35.0	889	...	85.5
225	107.2	...	18.9	38.5	978	...	77.8
230	110	...	20.8	42.3	1074	...	70.7
235	112.8	...	22.6	46.4	1179	...	65.1
240	115.6	...	25.0	50.8	1291	...	58.7

As the normal atmospheric pressure is 760 mm. or 29.9 inches it follows that as the temperature rises above 212° F. the atmosphere in an ager rapidly becomes unsaturated. In fact, at 230° F. this relative humidity is only 70.7% a figure no higher than that often reached on fine summer days.

When an ager commences to run the conditions would normally be favourable for the fixation of the leuco-compound on the fibre as the temperature is only about 216° F. but after running for some time conditions become less and less favourable, and, although the dyestuff may be perfectly reduced, less is fixed on the fibre, the resulting shades being weak.

The time taken to obtain the highest colour value that can be obtained from a print varies from dyestuff to dyestuff, and at the best it is only possible to obtain an average, for no matter under what conditions the colours are processed some will show improvement with increased ageing times, while others will actually give worse results when so treated.

Prints vary in character, dyestuffs vary in properties and every works evolves a set of conditions with the machinery available so that the most consistent results are obtained. Where heavy prints are the rule and overheating is prevalent, the dyestuffs favoured will be those which are very easily fixed under adverse conditions, whilst a works printing mainly fine shirting stripes or widely spaced patterns will find that their range of available colours is much greater.

Laboratory aged patterns show that at a temperature of 216° F. a period of eight minutes usually gives the best results, whereas when the temperature is restricted to 212° F. it is necessary to age for a period of approximately twenty minutes to obtain good results. In neither of these cases does the heating effect of running bulk come into play. Many works report that they are able to age their vat prints in less periods and in some cases three-and-a-half minutes has been cited as a suitable time.

It therefore appears that the initial overheating is beneficial as regards curtailing the time of processing. On the other hand the more rapidly the process is carried through, the more pronounced will be the differences due to any variations in conditions that may occur. A slowing down of the process would make variations less frequent and render control easier. The festoon type of ager in which the time of processing is 15 to 20 minutes probably depends to a large extent upon this factor for its efficiency.

Were it possible to run continuously on one pattern under standard conditions, a state of equilibrium would eventually develop and constant results would probably be obtained, but whether these would be good or bad would depend upon circumstances.

Cloth printed with small objects widely spaced would soon reach a state when the heat losses balanced the gains and consistent shades of comparatively good value would result. Cloth printed with blotch patterns would only slowly become stabilised and the results at that stage would be of very poor value for the dyestuff applied.

In practice rarely if ever is it possible to run one pattern for any length of time as the ager must cope with the production of many printing machines.

Conditions are therefore continuously changing but by running heavy and lightly printed patterns alternately it is possible to obtain conditions which produce results of fairly regular quality. When ageing long runs of heavily printed goods it is often necessary to run a few lumps of greys from time to time to prevent undue increase in temperature. This is expensive as it reduces the production of the machine, wastes time, and on account of the tendering action of repeated ageings on cotton, causes the Bump and Back Grey Account to mount unduly. By copious supplies of steam this rise in temperature can be counteracted to some extent, provided that the internal circulation of steam is efficient.

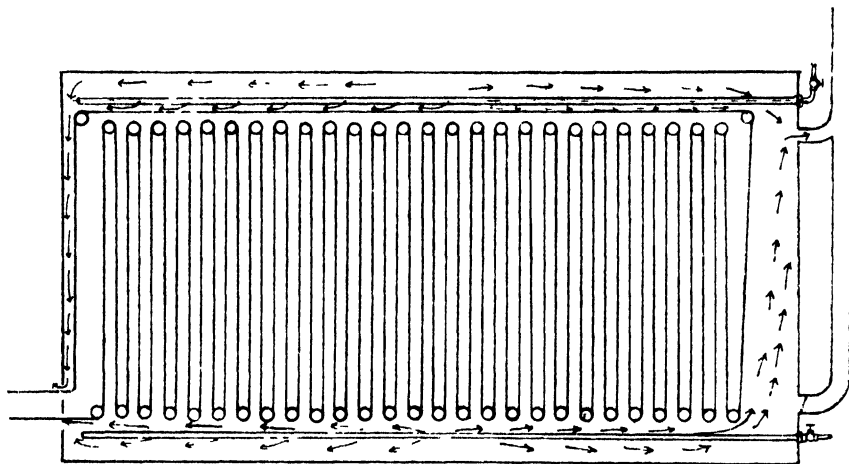


FIG. 1

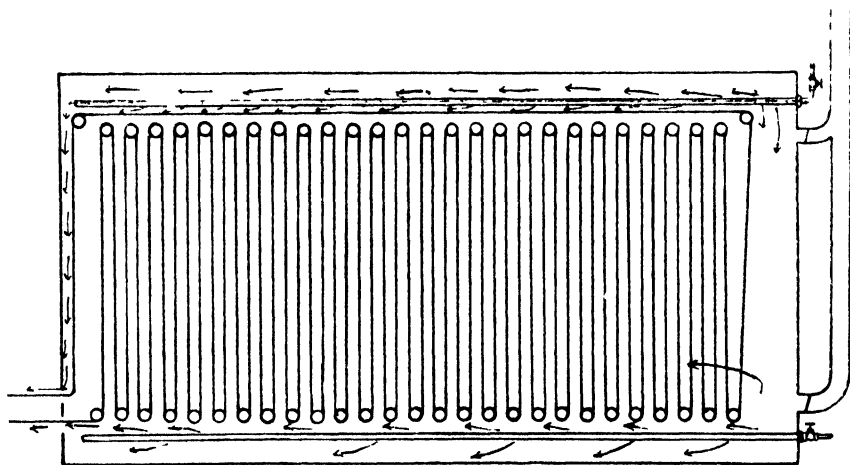


FIG. 2

There appear to be two opinions as to the better way of providing for the exit of the spent steam, the first asserting that mouthpiece ventilation is sufficient, whilst the second contends that ventilators at the rear of the machine are essential. Similarly there are several ways by which the steam is allowed to enter the machine, from the steam main via perforated pipes along the bottom and/or the top, from perforated pipes placed between the folds or by boiling water in the bottom of the machine by closed steam coils.

Whichever method is adopted it can only give satisfactory results when the steam has ample circulation facilities and herein lies what is probably the biggest problem in ageing practice.

The threading of the cloth in the ager is indicated in Figs. 1 and 2, and as there are invariably easy passages from the bottom steam inlet pipe to the exits the bulk of the steam will pass via that route in preference to finding its way between the folds of cloth.

The ageing of narrow cloths in wide machines can only accentuate this trouble, for there are in such cases large spaces at the sides of the fabric, in addition to the space under the fabric.

When top perforated steam pipes are inserted matters are little better, for the horizontal threading of the fabric immediately below the upper space effectively prevents the bulk of the steam from this pipe entering the folds and short-circuits it direct to the exits. On this account the proportion of the steam passing through the ager which is actually used for cooling the cloth can only be small.

Under E.P. 282,133 a system was devised by the Grangemouth Works of the I.C.I. by which the steam is circulated across the folds of the fabric. All the other existing systems fail to prevent the selvages of the cloth from being subject to better conditions than the portions between the selvages, as all depend mainly upon vertical rather than transverse ventilation or circulation of steam.

An ager planned according to the scheme of this patent possesses cone-shaped fixtures on the sides. These are joined by a wide tube in which is placed a circulating fan. By this means the steam is circulated and the formation of accumulations of superheated steam under the tops of the folds is entirely prevented.

For many years it has been general practice to place thermometers not near the sides of the machine but well into the folds of the cloth.

At this point the temperature is greater than that at the side and a truer indication of the temperature of the cloth is obtained. It is, however, not a true indicator of the temperature at which the fixation of the dyestuff is taking place, as the bulb is not in actual contact with the cloth.

In the Mather & Platt type of machine the first rollers are continually being fed with fresh supplies of cloth which are generating heat from the absorption of moisture. In consequence the temperature of these rollers most become much greater than that of the steam in the vicinity and it is my opinion that the temperature of these rollers rather than the temperature of the steam prevents the fullest colour value being obtained.

The sides of the machine do not come in contact with this source of heat and the portions of the rollers uncovered by cloth are also freely in contact with circulating steam. There is likely to be a temperature gradient from the centres of the rollers to the sides with a consequent greater fixation of colour on the selvages, and the more near ideal are the conditions at the sides the more noticeable will be the effect. To prevent this the printer is obliged to render the conditions of the whole of the machine less efficient, as otherwise the majority of his production may become jobs.

Unless maximum colour value can be obtained regularly and consistently it is of little value, for the saving in colour cost would be far outweighed by the increase in the allowances account.

Dissipation of the heat generated by the use of copious supplies of steam suffers from the drawback that the increased temperature of this steam affects the whole of the interior of the machine, and were it possible to remove the heat in the regions in which it is formed more regular results would be obtained. Cooling of the rollers internally would achieve to a large extent this object. As cooling agents neither water nor steam could be used, for water drops would result from steam as the rollers would collect water when the machine was stationary, and it could not be removed sufficiently rapidly by any system of buckets.

EXAMINATION OF THE INSTITUTE

For the current year, the Examination of the Institute, in connection with applications for the Associateship took place on the 14th June (Part I) at Manchester, and on the 21st June (Part II) at Manchester, Glasgow, Leicester, Belfast, Bombay, and Calcutta. For the information of members and others interested the examination papers are recorded as follows—

EXAMINATION PART I (Auxiliary Subjects)

CHEMISTRY

9.45 a.m. to 11.15 a.m.—14th June 1933

Candidates to answer THREE out of FOUR Questions

- (1) What do you understand by the term "element"? Describe the principal properties of the element chlorine. Mention three compounds of chlorine which are important industrially, and give one instance of a technical application in each case.
- (2) What is meant by the statement that iron is capable of forming "ferrous" and "ferric" salts? How would you distinguish chemically between the two classes of compounds? Suggest a method of converting ferrous sulphate into ferric sulphate.
- (3) How much quick-lime containing 80% CaO is required to causticise the sodium carbonate in one ton of a 10% solution of the latter, assuming that the actions which take place may be represented by

$$\text{CaO} + \text{H}_2\text{O} = \text{Ca(OH)}_2$$

$$\text{Ca(OH)}_2 + \text{Na}_2\text{CO}_3 = \text{CaCO}_3 + 2\text{NaOH}$$

(Ca=40, O=16, H=1, Na=23, C=12.)
- (4) How would you prepare a specimen of pure crystalline sodium chloride from sea water? By what means could its purity be established?

PHYSICS

11.30 a.m. to 1 p.m.—14th June 1933

Candidates to answer FOUR out of FIVE Questions

- (1) How would you find the density of a solid of irregular shape?
- (2) Describe the construction of a thermometer. How would you check the accuracy of a thermometer? Convert the following temperatures, expressed in degrees Centigrade, into degrees Fahrenheit—(a) 20° C., (b) 34° C., (c) 64° C., (d) 100° C.
- (3) Define the terms "heat" and "temperature" and describe experiments to illustrate the difference, if any, between them.
- (4) If you were given four 60-watt electric lamps made by four different manufacturers how would you determine whether they emit equal amounts of light?
- (5) What is Ohm's Law? How would you find out if the electrical resistances of two pieces of wire were similar?

MATHEMATICS & MECHANICS

2.0 p.m. to 4.0 p.m.—14th June 1933

Candidates are required to attempt no more than SIX Questions, FOUR of which must be those marked *

- (1) (i) Reduce to its simplest form—
 $\frac{3}{8} + \left\{ \left(2\frac{7}{8} - 1\frac{1}{8} \right) \times 1\frac{3}{4} \right\}$
 (ii) Calculate the values of—
 $40.15 \times 0.067 \div 0.73$ and $\frac{1}{\sqrt{20} - \sqrt{10}}$
 each correct to two decimal places.
- (2) Simplify—
 (i) $(3x-2)(2x-3) - (2x-5)(x+5)$
 (ii) $1 - \frac{1}{x+1} - \frac{1}{1-x}$
 (iii) $x^2 - 2x - 35$
 $30 + 11x + x^2$
- *(3) (i) Solve the simultaneous equations—
 $4x - 3y + 4 = 0$
 $6x + 4y - 11 = 0$
 (ii) If $A = \frac{7-x}{x}$, $B = \frac{x+1}{x}$, and $A^2 - B^2 = 1$, find x .
- (4) A tin box with a square bottom, open at the top, is to be constructed to have a capacity of two cubic feet. If the total area of the bottom and sides is A square feet, and the length of each edge of the bottom is x feet, express A in terms of x . Draw a graph showing the relation between A and x , and hence estimate the least possible area of sheet tin that could be used to construct the box.
- (5) (i) A pentagon (not a regular one) has three of its angles each equal to 150° . If the two remaining angles are equal, find them.
 (ii) If each of the internal angles of a certain *regular* polygon is 150° , calculate the number of sides of the polygon.
- *(6) State and prove the construction for drawing the tangents to a given circle from a given point.
 A chord AB of a circle is 4 inches long and is tangential to a concentric circle. Calculate the area of the annulus between the two circles.
- (7) A taut crossed belt passes round two pulleys of radii 6 in. and 12 in. and the distance between their centres is 3 ft. Find the angle at which the belt crosses itself and the length of the belt.
- *(8) Prove the formula $a^2 = b^2 + c^2 - 2bc \cos A$.
 If the sides of a triangle are 5, 7, 8 inches, prove that one of the angles is 60° .
- (9) An aeroplane which flies at 70 miles an hour in still air is to be flown from a place A to a place B, 130 miles due east of A. If there is a wind blowing at 30 miles an hour from the north-east, in what direction must the aeroplane be headed, and how long will the journey take?
- *(10) A car moves from rest with acceleration 2 ft. per sec. per sec. for 15 seconds, and then is brought to rest by a retardation of 3 ft. per sec. per sec. How far does the car move from rest to rest?

ESSAY

4.15 p.m. to 5.45 p.m.—14th June 1933

Pay special attention to the paragraphing, punctuation, spelling, and handwriting**Write not more than 5 pages on ONE of the following subjects—**

- (a) The Autobiography of a Shuttle.
- (b) Methods of Advertising.
- (c) "The friends thou hast and their adoption tried
Grapple them to thy soul with hoops of steel."
- (d) International Disarmament.
- (e) Some People I know.
- (f) The Seashore.
- (g) The Value of a Hobby.
- (h) Camp Life.

EXAMINATION PART II

GENERAL TEXTILE TECHNOLOGY

SECTIONS I AND V OF SYLLABUS

10 a.m. to 1 p.m.—21st June 1933

Candidates to answer THREE out of FOUR Questions in each Section**Section I—Fibres and their Production**

- (1) State briefly what you understand by the following terms— merino wool, crossbred wool; mungo; slipe; tow; line yarn; organzine; immature cotton; nep; sledded cotton.
- (2) Write a short essay on the production of raw silk.
- (3) State the characteristics and uses of the various types of British wools.
- (4) Describe the differences in structure and properties between the natural cotton fibre and the viscose rayon filament. Explain how the characteristics of these textile raw materials influence their utility.

Section V—Analysis and Testing of Raw Materials, Yarns, and Fabrics

- (1) What defects may be produced in the finished cloth by the following—
(a) uneven tension in rayon winding, weaving, or knitting; (b) variation in yarn twist; (c) thick and thin places in the yarns.
- (2) Discuss the term "staple length" and the methods used for its determination.
- (3) Describe how you would measure the following fabric properties—
(a) breaking load (tensile strength), (b) bursting strength, (c) ballistic strength, and (d) resistance to wear.
- (4) Discuss the methods which have been suggested for the measurement of the degree of chemical degradation of cellulose materials.

SECTIONS II, III, AND IV OF SYLLABUS

2.30 p.m. to 5.30 p.m.—21st June 1933

Candidates to answer TWO out of THREE Questions in each Section**Section II—Conversion of Fibres into Finished Yarns**

- (1) What are the desirable characteristics in standard warp, weft, and hosiery yarns and by what methods are they produced?

- (2) Mention the operations involved in the conversion of raw material to finished yarn in any two of the following sections of the spinning industry—(a) woollen; (b) worsted; (c) cotton; (d) spun silk or thrown silk; (e) rayon; (f) dry spun or wet spun flax; (g) hemp or jute.
- (3) Why is atmospheric humidity important in yarn manufacture? Describe how humidity may be measured and controlled.

Section III—Conversion of Yarns into Fabrics, and Fabrics produced by Special Methods

- (1) Write descriptive notes on the following knitting terms—welt; slack course; needle lines; sinker lines; lean fabric; running-on.
- (2) Compare the nature and properties of silk, cotton, rayon, and worsted yarns. In what manner does each yarn differently affect the woven design? What do you consider to be the particular merit of each class of yarn and for what type of fabric is it specially suitable?
- (3) What do you understand by the terms—(a) tappet shedding motions, (b) dobby shedding, and (c) jacquard machines and harness mounting, as applied to power-loom weaving.

Section IV—Conversion of Fabrics into Finished Materials

- (1) Outline the various methods which have been used to increase the lustre of (a) cotton fabrics, and (b) wool fabrics, and those which have been used to diminish the lustre of rayon fabrics.
- (2) Describe the behaviour of viscose and acetate rayons respectively towards different kinds of dyestuffs. Show how use may be made of differences of behaviour to produce white and coloured, self-coloured, and two-coloured effects in fabrics composed of viscose and acetate rayon yarns.
- (3) Write an essay on the comparative advantages and disadvantages of washing or scouring textile fabrics in the rope form and in the open width respectively.

NOTES AND NOTICES

Textile Institute Diplomas

Elections to Fellowship and Associateship have been completed as follows since the appearance of the previous list (April issue of this *Journal*)—

FELLOWSHIP

DERRETT-SMITH, Donald Alford (Lambeg, Ireland).

ASSOCIATESHIP

ACKROYD, John Henry (London).

LANCASHIRE, John Bowmar (Leicester).

Testimonial to Professor A. F. Barker

A circular has been issued from the University of Leeds calling attention to the retirement of Professor A. F. Barker after occupying the Chair of Textile Industries for eighteen years. His association with the University began in 1884 when he commenced the study of Textiles in the Department which he was destined to lead for so many years. The circular adds—"Following a distinguished career as head of the Textile Department of Bradford Technical College for 21 years, Professor Barker returned to the University in 1914 and, to those who have known the Department of Textile Industries since then, it is hardly necessary to state that his leadership has been characterised by an abounding interest in all that might be expected to promote the welfare of the wool textile industry.

Long before it was generally recognised, he had emphasised the need for the application of scientific method to the problems of industry and had taken a leading part in the foundation of the Textile Institute and of the Wool Industries Research Association." After stating that Professor Barker is a Member of the Worshipful Company of Weavers, Freeman of the City of London, and Medallist of the Textile Institute, the circular states—"There is a widespread desire that services such as these to the teaching and practice of textile technology shall not go unrecognised. It has been decided to invite subscriptions to a testimonial which will be administered in accordance with his wishes. Besides making a personal presentation, it has been suggested that an 'A. F. Barker Scholarship or Prize' might be founded. Subscriptions will be received by Dr. J. B. Speakman, The University, Leeds, and a list of subscribers will be presented to Professor Barker without indication of the amount of individual donations."

Institute Annual Competitions

As the final date for receipt of entries for the Institute's Annual Competitions has now passed, it is possible to record the number of registered participants for the current year. The principal or "A" Competition (Design and Structure of Woven Fabrics) has produced 14 entries; "B" Competition (Yarns) 10; "C" (Special Woven Fabrics) 20; "D" (Woven Fabric—Special Students) 17; "E" (Knitted Fabric) 17; "F" (Designs for Printed Fabrics) 23 and 10 in Class I and Class II respectively. The total is therefore 120 and the prize-money offered amounts to £180. The competition in relation to designs for printed fabrics forms an entirely new feature of the Institute competitions. The entry is not large for a competition of this character, but participation is limited to competitors under 24 years of age at time of entry.

Institute Membership

At the *June* meeting of the Council, the following were elected to Membership of the Institute: *Ordinary*—A. Leeson, Jennings & Leeson Ltd., North Bridge, Leicester (Representative Member for Leicester Chamber of Commerce, Hosiery Manufacturers' Section); T. H. Richmond, 39 Tullideph Road, Dundee (Partner, Richmond Bros., Art Fabric Manufacturers); E. Salt, 58 Queen Street, Leek, Staffs. (Designer and Colourist); Emma Stott, B.Sc. (Leeds), Ph.D. (Leeds), Department of Textile Industries, The University, Leeds (Research Assistant). *Junior*—J. H. Given, 35 Halifax Road, Briercliffe, nr. Burnley (Student). *Life Membership*—Dr. T. Oliver, 90 Channel Street, Galashiels, Scotland.

At the *July* meeting of the Council, the following were elected to Membership of the Institute. *Ordinary*—A. G. Ashcroft, Alexander Smith & Sons Carpet Co., Yonkers, N.Y., U.S.A. (Product Engineer, in Charge of Physical Testing and Research on Materials); A. N. Das, B.Sc. (Cal.), B.Sc. Tech. (M'cr), A.M.C.T., College of Technology, Manchester; T. L. Elhott, F.C.S., c/o Peter Spence & Sons Ltd., National Buildings, St. Mary's Parsonage, Manchester (Technical Sales Organiser); G. V. Hirst, 387 Rooley Lane, Bradford (Colour Matcher, Spinning Department); R. Lightbown, B.Sc. Tech. (Textile Industries), A.M.C.T., Beacondene, Earnsdale Road, Darwen, Lancs. (Technical Assistant in Liaison Dept., British Cotton Industry Research Association); A. Mellor, M.Sc. (Leeds), A.I.C., Belmont, Cherry Tree Hill, Chaddesden, nr. Derby (Chemist, British Celanese Ltd.); C. O. M. Steward, A.R.C.S. (Lond.), W. & J. Whitehead (Laisterdyke) Ltd., New Lane Mills, Laisterdyke, Bradford (Research Chemist); H. Fearnley, John Whiteley & Sons, Brunswick Mills, Halifax (Representative Member for this firm); D. E. Kanga, R32 Jerbai Wadia's Chawl, Lalbaug, Parel, Bombay, India (Assistant, Finlay Mills Ltd.); A. F. Kertess, Ph.D. (Freiburg), Beech Lawn, Dudley Road, Manchester 16 (Technical Chemist, Textiles); *Junior*—J. R. Dickinson, 2 Summerville Road, Stanningley, Leeds (Assistant to Manager, Worsted Combing and Spinning Factory); E. G. Williamson, 8 Nab Wood Grove, Shipley (Textile Designer).

THE JOURNAL OF THE TEXTILE INSTITUTE

Vol. XXIV

AUGUST 1933

No. 8

PROCEEDINGS Annual Conference of the Institute*

Harrogate, 7th, 8th, and 9th June 1933

SOME GENERAL SOURCES OF FAULTS IN TEXTILE MATERIALS

By DR. L. L. LLOYD
(Bradford Technical College)

Chairman Mr. E. T. HOLDSWORTH

Standardisation of processes from raw material to finished fabric is essential for the production of fabrics that are practically free of faults. In standardising processes it is absolutely essential that teamwork be organised in each section of the industry, and only in this manner is it possible to obtain superior results of one even nature for each type of fabric produced. Failure in the selection of uniform materials that are used in any process may lead to irregularities in one batch of material compared with other batches. This is particular where two different fibres are blended together before spinning. To give uniform results, not only the same weights must be blended, but also the two materials should have as near as possible the same staple lengths. This is illustrated in a union of viscose and wool; two runs were used, in one of which the viscose was shorter in length and consequently worked more on to the face of the fabric during finishing, the result giving a barry effect. The ratio of the fibres is the same but the whiter bars contain shorter viscose. It is necessary for managers and for workmen to recognise that without teamwork many a piece has been condemned long before it reaches the dyer or finisher. Many dyers, especially those that understand the finishing operations, may make a merchantable fabric from a material that had been poorly prepared by previous operations, but as a general rule this should not obtain. The preparer, the dyer, and the finisher should each assert his skill to produce from fabrics the best material possible from the goods produced by the manufacturer. The average mill employé is anxious to perform his work well in the production of high quality materials, and as a rule the employé clearly understands the necessary procedure of his or her section of the work and does this work with the best of his or her skill. They sometimes, however, fail to appreciate that any deviation from the accepted method of dealing with any definite fabric may lead to trouble in a succeeding operation. The manager that can develop a sympathetic understanding, among the foremen of the various departments, of the problems and difficulties of other departments, and of the necessity of correlation of the different departments, will prevent many troubles in the establishment and lead to uniformity of products. In like manner the foremen of each department should endeavour to develop among the workmen appreciation of the necessity for regularity of treatment in any process, and of the dependency of the workpeople upon the manner in which each individual carries out their particular work. With worsted goods the foreman finisher usually has charge of the scouring, and

* This issue contains certain of the Papers read at the Conference, *in extenso* with the discussions that ensued. Other Papers will appear in a subsequent issue.

it should be his duty to state how each type of material should be treated. It should be the duty of workpeople to notify the head of the department of any irregularities that are observed, as in this manner faults may be prevented or the number reduced. This system should obtain in all branches of textile work. As an example a standard make of worsted cloth was produced on a loom in which the mails were rusted. The rust was collected by the oil present on the warp and crabbing fixed the oil so that it was not removed by normal scouring. The piece when finished had many dark lines warpwise, and these on analysis were found to contain more iron than the remainder of the yarn, the amount varied in different parts of the yarn throughout the run of the fabric. By analysis it was impossible to state whether the oil that had been employed was a genuine olive oil, but it most probably contained some tea seed oil, as this oil is one that readily polymerises, and it has been found that iron promotes the polymerisation by heat, even crabbing is sufficient to produce this change. If the scourer had been notified that rust was present on the loom a solvent scouring method could have been used that would have eliminated the fault. Goods that are modified in this manner cannot be finished satisfactorily compared with unaffected material, if they are processed by the normal method and are then cobbled to attempt to correct them. Cobbling causes a modification of the properties of the wool fibre such that the same quality of finish is not obtainable. There are many commission dyers who treat all materials with solvent scouring agents because this overcomes many difficulties that are caused by the employment of unsuitable oils for the spinning operation. It is essential always to employ the same routine of processes on any one type of fabric if equality of finish is desired. In the production of woollens there is an axiom that no single department of the mill is able to rectify mistakes or damages made by other departments. The dye-house is probably the place where mistakes or damages will become evident. If the cloth has not been properly processed before being dyed, it is hopeless to expect this process to rectify it. In such cases the material should be sent back for rectification as far as is possible. Scouring and milling are sources of many faults, but with woollens carbonising is the root of many defects. The uneven distribution of sulphuric acid is one of the chief causes of colour defects, and another is that of uneven heat treatment during the baking of the acidified material. There is no doubt that open width squeezing is the best method, but this should be followed by slow evaporation of the moisture before heating to the desired carbonising temperature. Squeezing in rope form, followed by open width squeezing, is the best method for obtaining even acid content in the materials before drying and baking. A varying acid content will modify the dyeing properties of the wool, which may be an increased affinity of the wool for colour, or it may act as a resist. Again many dyers have the idea that the use of large quantities of Glauber's salt will give level dyeing no matter what percentage of acid is in the goods; such dyers do not rinse the goods well enough to lower the acid content and obtain a uniform acid distribution. Many woollens dyed under these conditions show a skittery appearance which in most cases may be prevented if the goods are well rinsed in the winch machine and then boiled with as short a bath as possible along with a neutral foaming agent such as melioran, Igepon or Gardinal. The bath may then be cooled by addition of water and the dyeing operated in this bath. The foaming agents will aid level dyeing and also aid in the production of a soft handle. The new Spooner Carbonising Plant, in which the material is carbonised without the use of a tentering system, has many advantages over other machines, and is applicable to all varieties of wool goods.

The use of highly-twisted yarns has greatly increased the necessity of sighting of these yarns for weaving, and many defects, particularly with regard to colour, are due to the nature of the sighting colour. Soluble Blue and Magenta are largely used for this purpose. These colours are apparently discharged during the scouring operation. They are, however, not removed but are so greatly reduced

in intensity that they appear free of colour, but when the goods are treated in an acid bath the colour returns. This occurs during the dyeing operation, often with unpleasant results because the tinting of the twist yarns is not even and the colour also affects the shade of the dyed materials. Insoluble coloured compounds are favoured by many spinners, particularly of yellow ochre and of ultramarine. With many highly twisted yarns it is almost impossible thoroughly to remove these substances during the scouring operation, with the result that the shade of the final product is impaired. These substances are removed, by scouring, from the outside of the yarn, but not from inside, and by subsequent processing they often work to the surface and thus cause a blemish. These substances are often used to colour a top very heavily indeed, some of this top being then blended with white wool for the production of tinted yarns. Insoluble coloured substances do not combine with the wool and consequently, during processing, there is always the possibility of these agents contaminating the atmosphere of the spinning and weaving sheds. Insoluble compounds of this nature may constitute a danger to the health of the operatives because they are in such a finely divided state, such that they readily remain in the atmosphere and may consequently become deposited in the lungs of the workpeople. There are many dyestuffs used for tinting purposes that are satisfactory for the tinting of woollen and worsted yarns, provided that the material has not to be submitted to a high temperature wet process, crabbing being probably the most damaging treatment because it fixes the colour. There are some six shades of "Fugitol" tints that are satisfactory for practically every purpose. These colours are removed from the material after crabbing by any acid process that follows, such as in dyeing; they are removed to a very great extent by scouring and do not colour any other yarns, with the possible exception of cellulose acetate rayon. As these colours are mainly used for tinting crêpe yarns, they will be removed in the acid bath in which the material is crêped. It appears to be necessary to utilise colours for tinting purposes that are practically fool-proof because tops are often tinted for a definite purpose and are then used for an entirely different one. Indigo-carmin has been used for a long time as tinting agent and is satisfactory provided that the colour is removed before any heat treatment is applied, but should the yarn after weaving be submitted to a crabbing operation the colour becomes fairly fast to alkali and leads to colour defects with piece-dyed goods. Many direct cotton colours have also been used, but with these again there is the difficulty of complete removal. With such tints removal with hydrosulphite is usually employed for complete removal, a process which increases the cost of finishing, and also modifies the finish of the goods.

Many of the tinting agents that are supplied commercially are tested by those that use them immediately after application to the material. In this condition they may be removed by cold scouring, but this is not sufficient to find whether they are affected by other operations that prevent their removal by scouring. The tinted yarn should be submitted to every possible operation to which it may be submitted before testing to find whether it is removed by scouring.

Wax rods as an aid to weaving may be of great assistance to the manufacturer but they are a great hindrance to the dyer and finisher. These rods are made of paraffin wax which is extremely difficult to emulsify, and consequently mainly remains on the material after scouring. Defects produced by wax are mainly present in goods produced from cellulose acetate rayon warps, although other fabrics also suffer. The trouble with goods containing cellulose acetate rayon is that they cannot be rigorously scoured by alkaline scouring agents on account of the effect of hydrolysis of this compound. The hydrolysis of the cellulose acetate rayon modifies the dyeing properties such that direct cotton colours will then heavily colour the fibre, thus preventing contrasting shades from being produced when this fibre is woven along with viscose rayon or other yarns. Paraffin wax is more easily removed by the employment of solvent scouring agents but most of these affect the cellulose acetate rayon. Paraffin wax in

such goods causes very obvious defects from the power of the wax to dissolve dyestuffs that are used for the dyeing of cellulose acetate, and as the paraffin generally collects as globules between the interstices of warp and weft they become very prominent after finishing. Lubrication by wax rods prevents the cracking of the warp yarn as well as aiding the weaving operation in the loom, but as paraffin wax is not readily removed it should be replaced by a preparation that is readily emulsifiable. Such wax rods are now available, made of material that is readily emulsified, which has no injurious properties and has been found in practice to be perfectly satisfactory. They are more expensive than paraffin wax, but their use would be an economic one. As far as I am aware, the first emulsifiable rods were produced in Italy, but these were too soft compared with paraffin wax, and although they gave fairly good results, they were not entirely satisfactory for manufacturers. The new rods are slightly dark in colour but they do not transfer any colour to any textile fibre after removal by the scouring operation. The presence of paraffin wax on textile materials, when it is unevenly distributed, has the effect of modifying the shade by altering the light reflecting properties. In some defects of this kind, since the wax is applied to the warp, and usually varying in degree between different threads, a dull warp streakiness is produced, the defect being observed only after finishing, and is caused by hot pressing, which slightly diffuses the wax into neighbouring threads. In my opinion this defect has often been reported as being due to the use of unsuitable oils for blending or spinning purposes.

In the knitting industry many colour defects are produced through carelessness; as an example the sample submitted for examination was produced from a six-fold feed, of which fine cheeses were from one run of yarn and one cheese of another. The two colours are easily recognised by the eye as being different shades, yet in this instance two reports were necessary to decide how the fault was caused. The two yarns differ in shade, in counts and in twist, but the defect was at first stated to be due to poor dyeing. It is perhaps as necessary to work up separate runs of yarn of the same shade and dimensions as is necessary in the woven goods trade. For the prevention of this fault it is necessary for the manager or foreman to educate the workpeople to compare the colour of the cheeses before feeding on to the machine, and should there be any noticeable difference to report to the foreman. Variation of the moisture content (condition) of all types of yarns leads to a large variety of defects, whether produced from dyed yarn or from undyed yarn. The variation of moisture affects the subsequent shrinkage during finishing as well as variation due to tension which readily affects over-conditioned yarn. Again tension is of very great importance especially when the goods have to be piece dyed. On account of shrinkage many knit goods are rapidly scoured and consequently are poorly washed, with the result that insoluble soaps are often left on the goods. These not only affect the colour but are also a source of bad odour which gradually develops when the goods are stored. This fault is also common with scoured dyed yarn for the knit goods trade. The use of the neutral foaming agents applied from an acid bath are of great value for the removal of insoluble soaps and they also improve the handle of the goods produced. Cleanliness of machinery is as necessary with knitting machines as it is with looms. Rusty needles are a source of rust stains which cause many troubles during dyeing and finishing. One of the most serious defects is that due to rust stains when the goods have to be peroxide bleached. The rust acts as a catalyst causing rapid decomposition of the peroxide such that the rust stains cause local excessive action with the result that the wool is decomposed, usually with the formation of holes where the rust stains were. This, of course, cannot be detected in the finished material and one has to surmise that it was caused by either copper or iron stains. If rust or copper stains are observed after scouring they should be removed before bleaching; the rust stains by means of oxalic acid, preferably followed by treatment with a neutral foaming agent, and the copper by a cold solution of cyanide

followed by well rinsing. If the material has to be dyed the stains should also be removed because they affect the shade of so many dyestuffs. Another blemish is that due to the use of jute packs that have been produced from dyed jute. The usual colour of dyed jute for this purpose is a deep blue produced by means of a basic dyestuff. Very small amounts of this dyed jute get into the raw wool and cause contamination of the whole batch of wool. The jute is partly removed during carding but much of it is powdered or broken into very small fragments which adhere to the wool. If the jute were undyed it would not cause a blemish in white goods, but the coloured jute is a source of small stains that impair the value of goods produced from such material. The jute is broken by the Harmel crusher into extremely small fragments which cause the blemish by colour bleeding during finishing; the colour bleeding mainly taking place when the goods are sulphur dioxide bleached or stoved. This trouble is a serious one because tops for this class of trade are produced without tinting, yet colour defects may develop that would be too costly to remove.

Oil stains are very common in knit goods, and are mainly produced by mineral oil used as lubricant for the machine. If the goods were scoured with the aid of a solvent scouring agent, the majority of these defects would be prevented. A much safer method would be that of using a blended oil for lubrication that would be readily emulsified by soap or soap and an alkali.

DISCUSSION

Professor A. F. Barker urged the importance of arousing the interest of the operatives in their work. Only by such means would it be possible to minimise faults and increase production.

Dr. A. W. Stevenson considered the intelligent mixing of yarns to be of the utmost importance. In a small-quantity fancy trade, such as the Scottish woollen industry, continual small surpluses of yarn were inevitable and the yarn man should know just how far he dare work these off in subsequent pieces without altering visibly the finished fabric.

Mr. F. Kendall said that he was glad that Dr. Lloyd had stressed the use of uniform and regular materials. This might be, commercially, difficult of achievement and an element of luck no doubt entered into the matter. He instanced the difficulties presented in securing repeat results in the use of crêpe yarns. To obtain such results year in and year out was extremely difficult.

Mr. George Garnett said that suggestions made by operatives should be welcomed, and advocated the offering of awards for any idea found useful. It should be remembered that the use of inferior raw materials was never satisfactory. Yardage from the looms was of the greatest importance and to secure a maximum only the best yarns should be used. This also applied to the oils employed, which should be the best procurable, though it was not easy to define which oils deserved this description.

Mr. I. E. Weber referred to copper stains which ultimately resulted in holes. These were now detectable in the early stages.

Mr. J. Chamberlain asked if the speaker could give a preparation for cleaning rusty needles and reeds.

Dr. Lloyd, in reply, recommended the use of a good mineral oil free from acid.

Mr. J. H. Strong said that for cotton goods he had always understood that vegetable oils should be used in preference to mineral oils if the goods had subsequently to be finished, and that mineral oils were difficult to remove.

Mr. J. H. Lester said that in his view the very interesting paper presented by Dr. Lloyd could be applied to cotton as well as to wool, and that it might also be applicable in the case of other fibres.

Mr. F. Wright suggested that while it was advisable to keep mixings uniform, it was, in these depressed times, not always practicable to do so. Few firms could maintain the stocks of raw materials such a procedure demanded. Where it could be done, the result in terms of fault elimination was bound to be satisfactory.

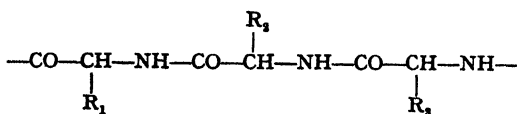
THE STRUCTURE OF THE WOOL FIBRE AND ITS RELATION TO FINISHING

By J. B. SPEAKMAN, D.Sc., F.I.C.

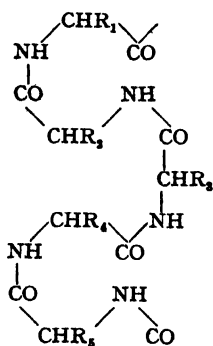
(Textile Chemistry Laboratory, Leeds University)

Chairman Professor E. MIDGLEY

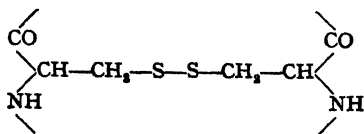
The wool fibre is now known to consist of micelles which are long in comparison with their thickness. They are probably lamellar in shape, their thickness does not exceed 200 A.U. and they are arranged with their long axes parallel to the length of the fibre.¹ According to Astbury,² the micelles are themselves composed of long peptide chains having the general formula—



which are folded into a series of pseudo hexagons as shown below—

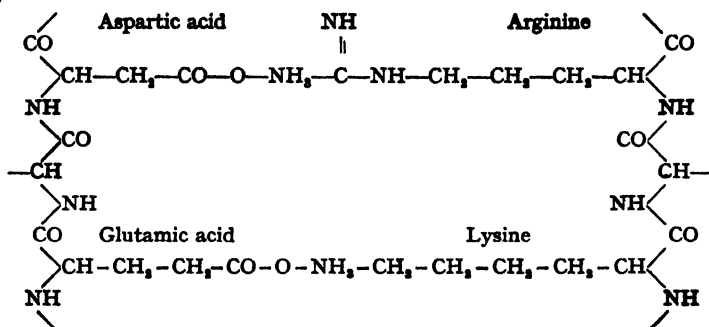


The groups R_1 , R_2 , R_3 , etc., represent side chains which are derived from amino acids bound into the peptide chain through α -amino and carboxyl groups. Such long folded chains run parallel to the length of the micelles and of the fibre, and the insoluble character of wool is determined by the length of the chains and the fact that they are bridged across by covalent and other linkages. From the point of view of the insolubility of wool, the cystine linkage is no doubt the most important, the peptide chains being bridged across as follows—³



In addition, they are linked by electrovalent (salt) linkages formed mainly from terminal amino and carboxyl groups of diamino and dicarboxylic acids, respectively.⁴ The acids and bases involved in salt formation are aspartic and glutamic

acids, arginine, lysine and possibly histidine. Typical linkages are shown below—



As will be shown later in the paper, such linkages as the above are of particular importance in relation to finishing processes and the action of water, acids, and alkalis on wool.

Besides such well-established linkages, other types must exist. In particular, a linkage possessing unusual properties is needed to explain the action of water on wool at high temperatures. So far this linkage has resisted all attempts at identification, but the information at present available will receive discussion later in the paper.

With the aid of this brief outline of the structure of the wool fibre, it is possible to discuss finishing processes in some detail.

GENERAL

The distance apart of the micelles of the dry wool fibre is so small that even molecules as small as those of glycerol are unable to enter the fibre structure. Water molecules, on the other hand, penetrate very readily, and by pushing apart the micelles, enlarge the capillary spaces within the fibre. For this reason, molecules which are normally unable to enter the fibre on account of their size, find penetration easy from aqueous solution. In the case of compounds which are insoluble in water, substances such as ethylene glycol, methyl and ethyl alcohols, and formic acid may be used as solvents because their molecules are small and have the necessary constitution to react with wool and enlarge the capillary spaces.

The restrictions imposed by the capillary structure of the fibre on penetration by molecules larger than *n*-propyl alcohol, except from solution in water and similar reagents, greatly limits the possible field of endeavour in attempting to develop new types of finish for wool fabrics. Many organic reagents, for example, which would be quite capable of reaction with proteins, are prevented by the size of their molecules from entering the dry, unswollen wool fibre and cannot be applied from aqueous, alcoholic or other similar solution because of their reactivity with such solvents.

On the other hand, restrictions of this kind are an important protection for the fibre against chemical damage. The greater compactness of the scale structure, as compared with that of the cortex, is of particular importance in this connection. In conjunction with Dr. N. H. Chamberlain it has been shown that descaled wool fibres adsorb colloidal cotton dyes such as methylene blue and chlorantine red with far greater ease than normal fibres. For example, descaled fibres readily adsorbed methylene blue in 1 minute at 100° C. from 0.05% solution in N/1000 to N/10 HCl. Untreated fibres, on the other hand, failed to adsorb dye until the concentration of HCl was N/10, when osmotic swelling is at a

maximum. It is significant that under the above conditions, neither descaled nor untreated fibres adsorbed methylene blue from solution in $N/1$ HCl where, in accordance with the Procter-Wilson theory,⁵ swelling is considerably reduced. The different swelling properties of scales and cortex revealed by the preceding experiments are due in part to the absence of histidine from the scales, but it seems probable that the crystal structure of the latter is more perfect than that of the cortex. From the point of view of finishing, the importance of the preceding results is in the proof they give that even aqueous solutions of colloidal substances will as a rule be restricted in their action to the surface of wool fibres, thus further limiting the possibility of developing new types of finish for wool fabrics.

Such are a few of the difficulties which must be overcome before any significant advances in the finishing of wool fabrics can be made.

The Action of Water on Wool in Relation to Finishing

In considering existing methods of finishing wool fabrics, attention will be restricted to processes which depend for their success simply on the action of water on wool. Besides increasing the size of the capillary spaces in the wool fibre, water molecules are able to enter the structure of the micelles themselves where they are adsorbed or combined with great evolution of heat. The water which enters the micelles minimises the forces of attraction between the long peptide chains and the oppositely charged ions ($-\text{COO}^-$ and NH_3^+) derived from salt linkages. Intermicellar water similarly reduces the cohesive forces between micelles. Since extension of the wool fibre has to be accomplished by uncoiling the long peptide chains against their mutual attractions, it is evident why wet fibres can be stretched more easily than dry ones. During extension, the positive and negative ions of salt linkages are separated, and recovery from extension is facilitated by their tendency to reunite. As will be shown later in the paper, this is not the sole cause of perfect elasticity in wool, and stresses within the peptide chains and their covalent side linkages must also assist contraction.⁶ Whatever the mechanism of contraction, however, it will clearly be facilitated by the presence of water.

Under the action of steam or boiling water, increased molecular vibration and reduced cohesion together cause rearrangement of the peptide chains and the ions derived from salt linkages, so that internal stresses are dissipated and the tendency for stretched fibres to contract in cold water is lost. Use is made of these facts in crabbing and blowing processes. If, however, the above were the sole mechanism of permanent set, fibres which had been steamed in the stretched condition should contract when resteamed in the absence of tension. That some contraction does occur on resteamng fibres which have been steamed at 30–40% extension for 15–45 minutes was shown to be the case in 1929,⁷ and this is the basis of the process known as steaming-off. In the experiments under consideration, fibre contraction was opposed by the weight of a small glass hook attached to each fibre at its lower extremity, and for this reason no "set" fibre was found to return to its original length on resteamng. More recently, however, fibres steamed for 15 minutes at as much as 83% extension were found to return to a length less than the original length in dilute caustic soda solution.⁸ Actually, supercontraction of this type was first observed with sodium sulphide solution, but dilute caustic soda solution and resteamng are more interesting as methods for removing "set" from wool fibres on account of their possible use for the production of *crêpon* effects in wool goods. Astbury and Woods have now found that if "set" fibres are resteamed in the *complete* absence of tension, supercontraction can be realised with fibres which have not been steamed originally for too long a time. The "set" produced by prolonged steaming, on the other hand, is not entirely eliminated by resteamng in the absence of tension. This

being the case, it is evident that strained fibres undergo some fundamental change under the action of steam. The molecular mechanism of permanent set is at present under investigation, and one fact of the greatest importance has been discovered. Since one cause of contraction in stretched fibres is the tendency of separated —COO^- and —NH_3^+ ions to reunite, it was expected that the removal of free amino groups from wool would facilitate setting. Experiments were therefore carried out with human hair which had been treated with sodium nitrite and acetic acid in the van Slyke concentration for 24 hours. The extent to which wool can be deaminated by nitrous acid is known to be dependent on a number of factors—concentration of nitrous acid, pH of the solution, temperature and time of treatment, but the great importance of fibre diameter was not known when the experiments under consideration were carried out. Cotswold wool fibres below 36μ diameter are completely deaminated in 24 hours by the

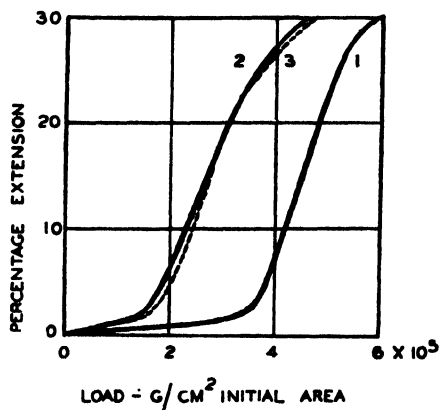


FIG. 1

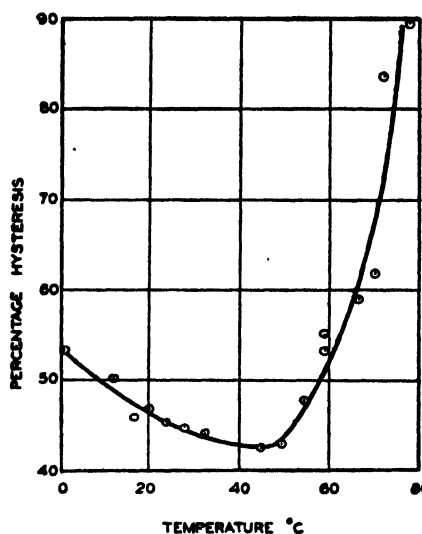


FIG. 2

van Slyke reagent, as shown in Fig. 1. Curve 1 of the latter is the load-extension curve of such a fibre in water at 22.2°C .; curve 2 relates to the same fibre in water after deamination; curve 3 (dotted) is that for the deaminated fibre in 1.043 N/10 HCl. Obviously the elastic properties of completely deaminated fibres are totally unaltered by the action of acid, in striking contrast with the behaviour of untreated fibres. From such experiments with Cotswold wool, it was assumed that 24 hours' treatment with the van Slyke reagent would suffice for the complete deamination of human hair, but this is now known to be improbable. Coarse fibres have been found to require longer treatment than fine ones for complete deamination, presumably because of the slow diffusion of nitrous acid through the fibre. Nevertheless the following experiments with human hair, deaminated by 24 hours' treatment with the van Slyke reagent, are entirely convincing.

A single fibre of deaminated hair was stretched 34.6% and steamed for six hours in this condition. Its rate of contraction in steam was then observed and compared with the rate of contraction of an untreated hair which had been

steamed for six hours at 38.2% extension. The results are summarised in Table I.

Table I

UNTREATED FIBRE			DEAMINATED FIBRE			
Time (minutes)		Extension %		Time (minutes)	Extension %	
0	...	38.2	...	0	...	34.6
10	...	25.3	...	15	...	10.5
30	...	22.4	...	60	...	2.1
150	...	13.3	...	120	...	—1.0
336	...	9.2	...	183	...	—3.6
376	...	8.8	...	423	...	—9.8
528	...	8.1				

Prolonged steaming is evidently capable of giving untreated hair a "set" which is only partially removable by steam, whereas similarly treated deaminated fibres are still able to contract to a length less than the original length. Instead of facilitating the "setting" of stretched fibres, deamination actually opposes the process. The result is of such importance that Mr. W. T. Astbury was asked to examine the properties of deaminated human hair by X-ray methods. It was found that deaminated hair, just like untreated hair, is transformed from the coiled (α) to the uncoiled (β) form of keratin by steaming at 35% extension. When allowed to contract in steam, however, the reverse transformation took place, a behaviour never previously encountered with "set" fibres.

In view of these results, it is certain that the free amino groups of wool are intimately concerned in the molecular mechanism of permanent set. The precise nature of the change is not yet understood, but it is interesting to draw an analogy with egg albumin. Just as wool fibres are incapable of taking a permanent set in the absence of water, so the denaturation of egg albumin by heat does not occur when the protein is completely dry. Denaturation is accompanied by a loss of affinity for both acid and alkali, which has been explained by assuming that —COO—NH_2 groups are converted into —CO—NH— linkages at 100° C. in presence of water. If such a reaction is possible with egg albumin, it should take place when wool fibres are steamed, and the mechanism of permanent set would then find a simple explanation—under the action of steam, the separated acid and basic side chains of stretched fibres regroup themselves, followed by conversion into —CO—NH— linkages, which would oppose contraction in cold water and in steam. Should such a transformation be possible, there is every reason to expect it to occur in the case of unstretched fibres. The only effect of three hours' steaming on unstretched fibres was, however, slightly to weaken them. They remained just as sensitive to the action of acid as before, so that it is difficult to believe that —COO—NH_2 linkages can be transformed into —CO—NH— linkages by the action of steam.

As regards the mechanism of permanent set, therefore, only two facts appear to be established: that water is essential and that amino groups play a determining part in the reaction. It seems likely that the first action of steam on *stretched* fibres is to open a linkage in the keratin molecule by hydrolytic action. The side chains so liberated must then react with the amino groups derived from salt linkages. On the basis of this hypothesis regarding the reactions undergone by stretched fibres in steam, it has been possible to devise a series of critical experiments which should serve to elucidate the nature of permanent set. The information at present available suggests that proline, oxyproline, serine, and tyrosine play an essential part in the process.

The action of water on wool at temperatures below 100° C. is also of interest in relation to finishing. Since water is adsorbed by wool with evolution of heat

the amount adsorbed at constant relative humidity should decrease with rise of temperature. At high relative humidities, this expectation is not realised, as shown by the data of Table II, which relate to Leicester wool under desorption conditions at 97.5% relative humidity.

Table II

Temperature ° C.		Percentage by Weight of Water Adsorbed
25	...	29.3
30	...	28.4
35	...	28.1
40	...	27.6
45	...	28.2
50	...	29.6
55	...	30.2

Above 40° C., the amount of water adsorbed increases with rise of temperature, and the most probable explanation of the phenomenon is that the expected decrease in the amount of water adsorbed is compensated by the creation of new surfaces available for adsorption. In other words, the micelles of the fibre must undergo subdivision in water at temperatures above 40° C., giving an increased swelling. Increased molecular vibration and reduced cohesion in water at high temperatures may lead to the separation in sheets of peptide chains linked laterally in one plane by covalent bonds. Alternatively, covalent linkages between peptide chains may be hydrolysed by water, but since the action of hot water on unstretched fibres is largely reversible, the former explanation of micelle subdivision is more probably correct. That such subdivision does occur is supported by the results of a study of hysteresis between extension and contraction of wool fibres in water at different temperatures. Data for human hair are shown in Fig. 2, hysteresis being expressed as a percentage of the work required to stretch fibres 30% in water at each temperature.

The action of hot water in subdividing micelles increases the accessibility of the wool fibre to dyes of high molecular weight, and this is one reason why wool is usually dyed at the boil. Other reasons are the increased dispersion and rate of diffusion of the dye itself at high temperatures. In connection with acid dyeing, however, it must be emphasised that acids are even more effective than water in promoting micelle subdivision. Representing the electrovalent (salt) linkages between peptide chains by $R_1\text{—COO—NH}_3\text{—}R_2$, the action of acids on wool may be summarised by the equation—



The linkages are opened, swelling forces are induced in accordance with the Procter-Wilson theory of swelling, and micelle subdivision is pronounced, especially in the case of weak acids. Peptide chains, linked laterally by cystine and perhaps other covalent bonds, are separated in sheets by swelling forces, but local distention of the chains within each sheet must also occur on account of the opening of salt linkages. Besides its interest in relation to dyeing, the action of acids (and alkalis) on wool is particularly important in relation to milling, but the process is the subject of a paper at present in the press⁹ and no attention need here be given to this branch of finishing.

A survey of the action of water on wool would not be complete without reference to the important part played by adsorbed water in determining the handle of a finished fabric. Any treatment which alters the affinity of wool

for water must produce corresponding changes in handle. Of particular importance in this connection is the way in which the affinity of wool for water depends on the temperature at which it is dried. The problem has been studied in conjunction with Miss E. Stott. Samples of purified Cotswold wool were first dried at 15° C. over phosphorus pentoxide and then allowed to adsorb water at 25° C. from atmospheres at 11.2, 24.5, 52.0, 69.8 and 89.4% relative humidity. After determining the amounts of water adsorbed by the several wools, they were dried at 25° C. and then again exposed to the same atmospheres as before at 25° C. The wools were afterwards dried at 36° C., followed by determinations of the amounts of water adsorbed at 25° C., and so on. A summary of the data obtained is given in Table III.

Table III

Temperature of Drying		Percentage by Weight of Water adsorbed at 25° C. at the following relative humidities—				
° C.		11.2%	24.5%	52.0%	69.8%	89.4%
15	...	4.57	6.98	12.37	16.29	23.52
25	...	4.23	6.76	12.00	15.94	23.32
36	...	4.05	6.65	11.76	15.64	22.84
48	...	3.94	6.49	11.57	15.53	22.91
59	...	3.87	6.48	11.58	15.60	22.78
76	...	3.74	6.33	11.58	15.41	22.61
80	...	3.74	6.33	11.51	15.55	22.81
98	...	3.60	6.16	11.38	15.25	22.32

In all cases, the effect of an increased temperature of drying is to reduce the affinity of wool for water. At the end of the above series of experiments, the wools were exposed to saturated air and afterwards allowed to attain equilibrium at the same humidities as before under desorption conditions at 25° C. The amounts of water adsorbed were precisely the same as for wool which had not been heated to a temperature above 25° C. In other words, the changes produced in wool by drying at high temperatures are eliminated when once it has been wetted out with water. All such results find a simple explanation in terms of Urquhart's theory of hysteresis in water adsorption, but the following observation presents a little more difficulty. When wool is dried from saturation at as high a temperature as 90° C., its affinity for water at 25° C. is almost exactly the same as that of wool dried at 25° C. Similar results were obtained with wool dried from saturation at 58.5° C. In view of the fact that when wool is heated with water at temperatures varying from 34° C. to 85° C. no significant alteration in the affinity for water at 45% relative humidity at 25° C. can be detected, it is difficult to understand why the affinity for water is not reduced by drying wool from saturation at high temperatures. From the point of view of industrial practice, however, the preceding observations are of importance as showing that control of drying conditions is most essential when the wool is not saturated with water.

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CLOTH MILLING WITH ACIDS

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Though certain acids have been employed in the milling of woollen cloth for a considerable number of years in this country, their use has been restricted to a few types of fabrics—mostly felts and uniform cloths; and their value as milling agents, and the possibilities they offer for more extended use, have not been generally recognised. On the Continent, and particularly in Germany, however, acid milling seems to have been practised for a much longer time, though, again, its usage has been confined to felts and heavy woollen cloths for piece-dyeing.

Incidentally, there is an interesting reference to a primitive form of acid milling in one of Pliny the Elder's works, in which he records that "the Gauls manufacture a kind of cloth without either spinning or weaving, which is said to be so strong when vinegar is used in the making of it, that it can withstand the blow of a sword."

Compared with the processes of soap and grease milling, treatment with acid affords a number of advantages, of which the following are the most important—

- (1) Acid is much more rapid in action, and is capable of milling the fabric to a greater extent.
- (2) It produces a fabric of much greater tensile strength.
- (3) It imparts a greater degree of extensibility or stretch to the fabric.
- (4) It conserves the wool fibres to a greater extent, so that there is less wastage by flocking, and the milled fabric, therefore, is heavier.

Many other advantages accrue from acid milling, chief amongst them being its value in dealing with fabrics dyed with acid colours, which might "bleed" if milled with soap. The dyes, actually, are fixed, and can, therefore, be employed even when very heavy milling is required. Also, the dyes are unaffected by the great increase in temperature which occurs during the process.

There is, also, an almost entire freedom from creases or "mill-rigs," which are often a very troublesome feature in both soap and grease milling; and curling-lists are considerably less in evidence.

In addition, the speed at which the process is carried out allows a very considerable increase of output, with a consequent reduction of production costs.

It is sometimes cited against milling with acid, that the fabric, after treatment, is inclined to be harsh in handle and lacking in surface cover. The former deficiency may be due to the action of the acid in slightly hardening the wool fibres. This, however, is only likely to occur in cloths made of very fine wools, and stronger-fibred wools of the Cheviot and crossbred types are not liable to be affected in this manner. The latter deficiency may be attributed to faulty working. Lack of cover often results from a loss of milling power at some stage of the process—due possibly to some factor not functioning properly.

ROUTINE PRACTICE OF ACID MILLING

Sulphuric, acetic, and formic acids are all employed as milling agents, the first named, however, being the one most commonly used on account of its cheapness. Hydrochloric acid, though not used commercially, is also quite an effective milling agent.

When sulphuric acid is used for milling, it is generally bought in the form of double oil of vitriol (D.O.V.), though brown oil of vitriol (B.O.V.) is sometimes substituted. The former, however, is more satisfactory owing to its greater strength and purity. The amount of acid used is based upon the weight of the scoured cloth. The following is a suggested routine of working—

Amount of Acid Used—D.O.V., 4 to 4½ lb. acid for 100 lb. of cloth, reckoned on the estimated dry scoured weight. This has been found to yield the most satisfactory results for many weights of both woollens and worsteds.

Preparation of the Acid Solution—Make a solution by mixing the required quantity of acid with water in a wooden bucket. The acid must be added to the water very slowly, and the solution gently stirred with a wooden or glass rod in order to ensure a thorough mixing.

Preliminary Scouring—The cloth, before milling, must be thoroughly scoured, and then well washed-off, so that all traces of soap are entirely removed.

Applying the Acid Solution—The solution may be applied to the cloth in the scouring machine immediately after washing-off. Half fill the machine with cold water, and start it so that the piece is moving whilst the acid is being added. Slowly pour in the solution from the front of the machine, trailing it across the full width. The concentrated solution must not come into contact with the cloth, or it will be taken up unevenly, and possibly cause uneven milling. Allow the piece to run in the solution for about 20 minutes; then drain the acid away, and squeeze out the excess moisture by running the piece in the now empty machine for a few minutes.

Alternatively, the cloth may be passed through the wringer, or hydro-extracted, but this treatment is inclined to leave the piece too dry. Some millers, also, after the acid solution has been drained away, prefer to rinse the cloth with cold water for a few minutes, the object of this being to ensure that the acid absorbed by the cloth is distributed evenly.

Milling—The piece is then taken to the milling machine. During this process it must be kept quite moist by the addition of warm water from time to time, in order to replace that lost by evaporation. There must be sufficient cloth in the machine to ensure a maximum of friction, otherwise the temperature will not rise high enough, and the milling action will be slow. When the temperature rises—and this should be considerably in excess of that obtained by soap or grease milling—it must be maintained.

Watch the length of the piece as milling nears completion; it is inclined to "jump" suddenly, and may, therefore, contract too much if the weights on the spout-lid are not adjusted.

Washing-off after Milling—Rinse the piece in the scouring machine for about 15 minutes, using warm water only. If necessary to neutralise the acid, add a little soda ash solution to the water, but rinse this away also.

THE "TIME" FACTOR IN ACID MILLING

The most important advantage accruing from the use of acid is the saving in time, because the speeding-up of the process enables a greater output to be obtained from the machine. This becomes especially evident when comparing the time taken for acid and grease milling respectively. Table I records the results of experiments in grease and sulphuric milling made on a woollen cloth of the uniform type, the component yarns being of a medium Saxony quality.

Table I
Contrasts between Grease and Acid Milling

			Grease Milled		Acid Milled
Grey length	...	...	65½ yards	...	65½ yards
" width	...	...	75 inches	...	75 inches
" weight	...	...	140 lb.	...	142 lb.
Scoured length	...	...	—	...	67½ yards
" width	...	...	—	...	70 inches
" weight	...	...	—	...	91 lb.
Milled length	...	...	61½ yards	...	56½ yards
" width	...	...	54 inches	...	55 inches
" weight	...	...	87 lb.	...	89 lb.
Duration of milling	...	...	10 hours	...	3½ hours

It will be noticed that the cloth milled in the grease took three times as long to attain the required dimensions as the one treated with the acid; and also, that

the acid-milled fabric has contracted 5 yards more in length than that milled in the grease, this being the reason for taking it from the machine at 55 inches wide instead of 54.

In making comparisons, however, of the times taken for grease and acid milling, it must be remembered that an acid-milled cloth has to be scoured before it can be milled; the time required for this process, therefore, must be included when reckoning the duration of acid milling.

Table II compares the times taken for milling a woollen cloth of Cheviot quality, in the grease, with soap, and sulphuric acid respectively, the fabric being composed of 15 skeins yarns, woven with 24 threads and picks per inch, and set 74 inches wide in the reed.

Table II
Dimension Contrasts between Grease, Soap, and Acid Milled Cloths

Stages	LENGTHS			WIDTHS		
	Grease in.	Soap in.	Acid in.	Grease in.	Soap in.	Acid in.
Greasy cloth ...	36	36	36	70	70	70
Scoured cloth ...	—	36	36	—	67	67
Milled 30 mins. ...	34	33	32	67	64	62
" 60 " ...	31	30	29	64	61	58
" 90 " ...	29	27	26	62	59	56
" 120 " ...	28	26	25	60	57	54
" 150 " ...	27	25	24	58	56	53
" 180 " ...	26	24	23	57	54	52
" 210 " ...	—	23	22	56	53	51

Milling was continued until each cloth had contracted to 56 inches in width. The shrinkages in length and width were recorded every 30 minutes as the milling proceeded. Reference to the table shows that the cloth milled with acid reached the required width in 90 minutes, the soap-milled cloth took 150 minutes, while the fabric milled in the grease required 210 minutes. The length shrinkages show that in 210 minutes the acid and soap-milled cloths had contracted to 22 and 23 inches respectively, but the grease-milled fabric had contracted to 26 inches only at the end of 180 minutes, and after this period no further milling action had taken place.

THE "STRENGTH" FACTOR IN ACID MILLING

The property, possessed by sulphuric acid, of imparting a greater degree of tensile strength to a fabric than is possible either with soap, or by milling in the grease, makes it of great value in the manufacture of uniform cloths. The figures recorded in Table III show the relative strengths—obtained at their various stages of milling—of the same fabrics of which the contraction ratios are given in Table II.

Table III
Comparison of Tensile Strength Tests after Grease, Soap, and Acid Milling

Stages	LENGTHS			WIDTHS		
	Grease lb.	Soap lb.	Acid lb.	Grease lb.	Soap lb.	Acid lb.
Greasy cloth ...	78.6	78.6	78.6	73.4	73.4	73.4
Scoured cloth ...	—	60.4	60.4	—	58.6	58.6
Milled 30 mins. ...	63.2	65.7	70.1	56.0	61.3	68.5
" 60 " ...	67.8	72.4	76.3	58.5	66.7	76.0
" 90 " ...	76.2	79.5	87.5	64.2	70.3	83.1
" 120 " ...	87.1	90.6	96.2	68.9	75.8	92.5
" 150 " ...	95.3	108.2	114.5	75.0	82.4	99.5
" 180 " ...	107.5	112.3	120.3	84.2	87.9	105.7
" 210 " ...	105.6	115.8	124.7	84.3	87.9	109.5

The figures show that the acid-milled fabric is considerably stronger than either of the other two at each of the several stages of milling. The fabric milled in the grease is the weakest, and actually lost strength in the final stage when it had ceased to contract.

In the generality of fabrics the tensile strength is greater in the length than in the width, both before and after the milling process. Sulphuric acid, however, will often produce a proportionately greater increase of strength in the weft than in the warp. This, therefore, is another valuable feature of acid milling, inasmuch, as it is possible to level-up the strength of the weft in heavily milled fabrics.

EXTENSIBILITY DUE TO ACID MILLING

Another advantage arising from the use of sulphuric acid is the increased stretching property or extensibility imparted to the fabric. Fabrics so treated invariably extend further before breaking than those milled in the grease, or with soap. The extensibility tests, set forth in Table IV, and obtained from the same fabrics from which the contraction measurements and tensile strength tests were taken, will serve to illustrate this statement. From the figures in Table IV it will be seen that the acid-milled cloth has the greatest, and the grease-milled cloth has the least stretching power. Also, that the extensibility of each fabric increases with each successive milling period. Furthermore, it will be observed that the extensibility is greater weftways than warpways. This last feature is explainable by two reasons, the first being that in weaving the warp yarns are maintained under a constant and regular tension, while the weft is inserted more or less loosely, with the tension varying from the start to the finish of the bobbin. The second reason is that a cloth is always milled to a greater extent in the width than in the length; in any given unit of measurement, therefore, there is always a relatively greater length of weft than warp to be stretched.

Table IV
Extensibility Measurements after Grease, Soap, and Acid Milling

Stages	LENGTHS			WIDTHS		
	Grease in.	Soap in.	Acid in.	Grease in.	Soap in.	Acid in.
Greasy cloth ...	1-72	1-72	1-72	1-64	1-64	1-64
Scoured cloth ...	—	1-65	1-65	—	1-70	1-70
Milled 30 mins. ...	1-66	1-78	1-88	1-99	2-26	2-33
" 60 " ...	1-72	1-86	2-23	2-34	2-37	2-45
" 90 " ...	1-98	2-12	2-31	2-42	2-48	2-56
" 120 " ...	2-25	2-38	2-46	2-58	2-62	2-74
" 150 " ...	2-40	2-46	2-61	2-65	2-72	2-87
" 180 " ...	2-48	2-58	2-67	2-73	2-82	3-09
" 210 " ...	2-52	2-71	2-78	2-76	2-98	3-26

EFFECTS OF USING VARIOUS STRENGTHS OF ACID SOLUTIONS

Variations in the strength of the acid solutions used, affect the rate and extent of contraction, the extensibility, and also the tensile strength of the fabric. Table V records the results of experiments made with different concentrations of pure sulphuric acid based on the weight of the dry scoured cloth, namely 1.5, 3, and 4.5%, and a further experiment, for comparison, made by milling a length of the same fabric with a good quality of hard soap. The cloth employed for the tests was made of ten skeins white Saxony noils, woven with 24 threads and picks per inch, set 72 inches wide in the reed, the weave being the 2-and-2 twill. Each cloth was milled for one hour.

An examination of the figures relating to length and width shows that the soap-milled cloth has contracted the least, and that in the three cloths milled with acid a greater and progressive degree of contraction has been obtained by the use of the stronger solutions. There is, however, very little difference between the soap-milled fabric and that treated with the weakest acid solution.

The extensibility figures are in accordance with those relating to contraction, i.e. the cloth that has contracted the least stretches the least, and the one that has contracted the most possesses the greatest power of extension.

The figures relating to tensile strength show that even the weakest acid solution produced a stronger fabric than that obtained by soap milling; and that as the acid solutions were increased in strength, the tensile strength of the fabric was increased also.

Table V
Records of Contraction, Extensibility, and Tensile Strength Tests on Cloths
Milled with Soap and Different Strengths of Acid

		LENGTHS				WIDTHS			
		Sulphuric Acid				Sulphuric Acid			
		Soap	1.5%	3%	4.5%	Soap	1.5%	3%	4.5%
		in.	in.	in.	in.	in.	in.	in.	in.
<i>Contraction</i>									
Scoured cloth ...	...	36	36	36	36	68	68	68	68
Milled 20 mins.	...	33	33	31	30	64	63	61	60
" 40 "	...	31	30	28	26	61	60	58	57
" 60 "	...	30	29	25	24	59	58	56	54
Sulphuric Acid									
		Soap		1.5%		3%		4.5%	
<i>Extensibility</i>		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
		in.	in.	in.	in.	in.	in.	in.	in.
Scoured cloth ...	...	1.86	2.12	1.86	2.12	1.86	2.12	1.86	2.12
Milled 20 mins.	...	2.14	2.15	2.12	2.21	2.27	2.38	2.40	2.53
" 40 "	...	2.52	2.46	2.48	2.48	2.52	2.58	2.59	2.64
" 60 "	...	2.53	2.69	2.50	2.62	2.62	2.71	2.73	2.79
Sulphuric Acid									
		Soap		1.5%		3%		4.5%	
<i>Tensile Strength</i>		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
		lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Scoured cloth ...	...	56.8	52.2	56.8	52.2	56.8	52.2	56.8	52.2
Milled 20 mins.	...	61.3	55.7	67.6	58.0	71.5	63.7	74.2	63.9
" 40 "	...	68.0	58.3	75.0	60.3	82.1	65.4	86.0	64.8
" 60 "	...	74.7	61.4	79.6	62.6	88.4	66.8	97.5	68.4

Acid milling solutions of from 4 to 4.5%, based on the weight of the scoured cloth, have been found to yield the most satisfactory results with regard to both contraction and tensile strength. Experiments made with stronger solutions indicate that contraction still continues with solutions up to 6%, but at that figure contraction ceases. Tensile strength increases with acid solutions made up to 8%, but drops sharply with stronger concentrations.

MILLING WITH ACETIC, FORMIC, AND HYDROCHLORIC ACIDS

Both acetic and hydrochloric acids give satisfactory results, producing a greater amount of contraction and stronger fabrics than by milling with soap, but not to the same extent as by using sulphuric acid. Table VI records the relative contractions and tensile strengths obtained from a series of experiments made with sulphuric, hydrochloric and acetic acids, and soap. The cloth used for the series was made of 20 skeins Saxony waste, woven with 26 threads and picks per inch and set 38 inches wide in the loom, the weave being the 2-and-2 twill. Pure acids were used, all made up to 4.5% on the weight of the dry scoured cloth.

Table VI
Dimensions and Tensile Strengths of Fabrics Milled with Sulphuric, Hydrochloric, Acetic Acid, and Soap

Stages	Lengths and Widths in inches							
	Sulphuric		Hydrochloric		Acetic		Soap	
	Length	Width	Length	Width	Length	Width	Length	Width
Scoured cloth ...	36	32	36	32	36	32	36	32
Milled 60 min.	26	23	27	25	28	25	27	26
" 150 "	20	18	22	20	23	19	22	20
Tensile Strengths in lb.								
	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
Scoured cloth ...	20.9	16.2	20.9	16.2	20.9	16.2	20.9	16.2
Milled 60 min.	46.8	41.2	44.8	42.6	40.7	38.4	39.9	36.5
" 150 "	77.0	71.2	74.2	70.1	71.5	66.0	71.5	65.7

In a series of tests made on a worsted cloth with sulphuric, acetic, and formic acids, the first named produced the most contraction and the strongest fabric, and the last named yielded the least contraction and the weakest cloth.

THE HYDROGEN PEROXIDE BLEACHING OF WOOL, COTTON, AND SILK

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As the subject of the paper is the bleaching of wool, cotton, and silk with hydrogen peroxide, an account of this chemical and its manufacture is of interest. Present-day methods for the production of hydrogen peroxide come under two headings—

- (a) Manufacture from barium peroxide.
- (b) Processes involving electrolysis.

The hydrogen peroxide made by either of the processes is entirely satisfactory for bleaching purposes. There appears to be considerable misunderstanding concerning the quality of hydrogen peroxide produced from barium peroxide. It is true that 15 to 20 years ago the quality of the hydrogen peroxide so produced was not altogether satisfactory. Very rapid strides, however, have been made in the improvement of this product, and to-day not only are the weaker strengths of hydrogen peroxide made from barium peroxide, but, in addition, hydrogen peroxide of 30% and 40% strength (by volume). Before 1925 hydrogen peroxide from barium peroxide was only made by the well-known method of reacting on barium peroxide with sulphuric acid alone or in the presence of small quantities of phosphoric and hydrochloric acids. This process has been entirely superseded by the method described under Patent No. 252,768, the basis of which is the reaction between barium peroxide and phosphoric acid. Whereas in former processes the hydrogen peroxide and barium sulphate (blanc fixe) were produced simultaneously, by this new method they are produced in two separate stages. The hydrogen peroxide thus obtained is of much greater purity, is approximately 15 volumes strength, and is a very stable product. This low strength hydrogen peroxide is then distilled to give a 30 or 40% hydrogen peroxide. The barium sulphate is also an immensely improved product.

Broadly speaking there are three practical methods for the manufacture of hydrogen peroxide by electrolysis—

- (1) The electrolytic production of ammonium persulphate, its conversion by double decomposition into potassium persulphate and the distillation of the latter with sulphuric acid to give hydrogen peroxide.
- (2) The electrolytic production of persulphuric acid and the distillation of this product to give hydrogen peroxide.
- (3) The electrolytic production of acid ammonium persulphate and its conversion by distillation to give hydrogen peroxide.

It will be observed that whatever the basis of the electrolytic process, finally a distilled hydrogen peroxide is obtained. This applies equally to our own methods of manufacture whether by the barium or electrolytic process.

Definition of Hydrogen Peroxide Strengths

Hydrogen peroxide is made in 10, 12, 20, 100, and 130 volume strengths. 10 Vols. strength H_2O_2 will give 10 times its own volume of oxygen

12	"	"	"	12	"	"	"
20	"	"	"	20	"	"	"
100	"	"	"	100	"	"	"
130	"	"	"	130	"	"	"

In view of the extended use of the higher strengths of hydrogen peroxide the following data relating to such strengths is useful—

Volume Strength	% H_2O_2	C.c. test of H_2O_2 by method given later	Density of H_2O_2 grms./c.c.	Concentration of H_2O_2 grms./litre
10	3% by vol.	35.7-36	1.01	30
100	30% by vol.	356-360	1.107	300
130	40% by vol.	467-472	1.137	400

Calculated at 15° C. and 750 mms. pressure.

The Estimation of Hydrogen Peroxide up to 30 Volume Strengths

Pipette 2 c.c. into 50 c.c. of water and add 50 c.c. of sulphuric acid 1:10. Titrate to pink colouration with N/10 potassium permanganate.

Using 2 c.c. of hydrogen peroxide for the estimation a one-volume hydrogen peroxide requires 3.57 c.c. N/10 $KMnO_4$ whence the volume strength equals

$$\frac{\text{c.c. N/10 } KMnO_4}{3.57}$$

The Estimation of Hydrogen Peroxide of Strengths Greater than 30 Volumes

Check a 25-c.c. pipette into a 250-c.c. flask. The volume delivered by the pipette must be contained exactly 10 times by the flask (at room temperature). 25 c.c. of the concentrated hydrogen peroxide are then pipetted into the flask and the volume made up to 250 c.c. with water at room temperature. After thorough mixing, pipette 2 c.c. of the diluted hydrogen peroxide into 50 c.c. of water and add 50 c.c. of sulphuric acid 1:10. Titrate to pink colouration with N/10 potassium permanganate.

The volume strength of the hydrogen peroxide equals

$$\frac{\text{c.c. N/10 } KMnO_4 \text{ required} \times 10}{3.57}$$

Volume strengths allow of a simple method of transferring from one strength of hydrogen peroxide to another. This applies equally to the making up of bleaching baths. Thus one gallon of 100 volume strength hydrogen peroxide will give 100 gallons of one volume strength hydrogen peroxide.

Stability of Hydrogen Peroxide

Owing to its freedom from impurities a good stable hydrogen peroxide should not lose its oxygen on storage or unduly in the bleaching bath. An acid solution of hydrogen peroxide is more stable than an alkaline solution and therefore all hydrogen peroxide contains a small amount of acid to render it stable in transit and up to the time of use when the liberated oxygen is required to do the bleaching.

In recent years considerable improvements have been made in the quality of hydrogen peroxide. Whereas in the British Pharmacopœia of 1914 the limit of acidity is given as 10 and the solid residue as 1%, in the recent Pharmacopœia, whilst no change was made in the limit of acidity, the solid residue was reduced to 0.2%. A good grade of peroxide of hydrogen comes well within this specification, the acidity being of the order of one-third and the solid residue one-half of that allowed by the Pharmacopœia.

An indication of the remarkable stability of the hydrogen peroxide manufactured to-day is shown by the following figures—

(a) 12 volume strength hydrogen peroxide.

Number of samples examined	Period of test	Average % loss of original strength
217	12 months	0.5
188	2 years	1.4

The above stabilities were determined at room temperatures (15-20° C.)

The stability of the hydrogen peroxide decreases with increase of temperature, but even so the quality of the hydrogen peroxide is such that under tropical conditions the strength is very well maintained; at a temperature of 35°-40° C. over a period of six months the loss being of the order of 2% of its original strength.

(b) Stability of 100 volumes strength hydrogen peroxide.

Number of samples examined	Period of test	Average % loss of original strength
80	12 months	2.0

Stability determined at room temperatures (15-20° C.).

Owing to the improvements that have been made in the stability of high strengths hydrogen peroxide it is now possible to ship a satisfactory product to tropical countries.

The Effect of the following Metallic Salts on the Stability of 10 Volume Strength Hydrogen Peroxide is of interest to the Bleacher.

Acidity of H_2O_2 = 8 c.c. N/10 NaOH to phenolphthalein required to neutralise 100 c.c. of the H_2O_2 .

The H_2O_2 with the added salt was boiled in a flask fitted with a reflux double surface condenser.

Salts used—Ferric sulphate, manganese sulphate, copper sulphate, nickel sulphate, chromium sulphate.

					% Loss of H_2O_2 after		
Time					1 hour	3 hours	6 hours
Blank	...	...	...	...	0.8	1.1	2.5
1 part per million copper	...	...	...	...	10.8	35.2	80.0
5 parts per million copper	...	...	...	...	38.8	93.8	—
10 "	"	"	copper	...	57.4	96.3	—
10 "	"	"	iron	...	2.6	4.6	13.9
10 "	"	"	manganese	...	1.1	2.4	18.0
10 "	"	"	nickel	...	0.8	1.8	3.8
10 "	"	"	chromium	...	1.5	8.0	22.2

The action of very small quantities of copper is particularly pronounced when compared with iron, manganese, nickel, and chromium.

History of Bleaching with Hydrogen Peroxide

It is rather interesting to note that *barium peroxide*, which for so long has been the raw material for the manufacture of hydrogen peroxide, was first used in the bleaching of silk. As is perhaps natural, this development took place in France, and Tessie du Motay patented a process in Great Britain, No. 4172, for the preparing and treating of silk with barium peroxide. The barium peroxide bleach was also recommended by him for the bleaching of wool. Three years later, in 1878, we discover that *hydrogen peroxide* was used for the bleaching of silk. This is a natural development, as the hydrogen peroxide would be made from the barium peroxide. It is evident that French dyers preferred to use barium peroxide at this period because of the instability of the hydrogen peroxide and its high cost.

The Jacobsens in Patent 1711 of 1882 covered the addition of such salts as alkali silicates, sal ammonia, borates, etc. to a barium peroxide bleaching bath in order to obtain gradual evolution of oxygen. They were of the opinion that such a method showed an advantage over hydrogen peroxide.

The use of barium peroxide as a bleaching agent has been rendered unnecessary by the improved methods of manufacture of hydrogen peroxide resulting in a very stable product at a much lower cost. To-day's price of hydrogen peroxide is approximately one-third of what it was in 1888.

From 1875 to the present day various attempts have been made to obtain the ideal bleaching conditions, and for simplicity a table is given of some of the more important methods which have appeared either in the patent or general literature.

Patent or Journal	Patentee or Author	Material Bleached	Strength of H_2O_2 Bath	Temperature	Alkali, etc for Neutralising	Time of Bleaching	Type of Bath	
1878 British Patent 1414	Lebou teux	Silk	$\frac{1}{2}$ vol	Cold 100–120° F	Ammonia Ammonium perchlorate hypochlorite nitrate arsenate, carbonate oxalate and formate	24 hours 12 hours	Steeping	
1887 <i>Leipziger Monatschrift</i>	F. Kruger	Wool	1%	—	Ammonia in excess	2–3 hours	Steeping	Where soda or lime used instead of ammonia excess alkali neutralised after bleaching with HCl or acetic
1887 <i>Textile Colorist</i>	Delmark	Wool	1–2 vols	Room temp	Ammonia pH 7	6–10 hours	Steeping	
1888 <i>J. of Soc. of Dyers and Colourists</i>	F. Bell	Wool	10 vols	—	Ammonia pH 7	—	Ageing	Material saturated and dried at 54–63° F and repeated to give desired white
			10 vols	54–63° F	Ammonia pH 7	24 hours	Steeping	
			10 vols	86° F	Ammonia pH 7	8–10 hours	Steeping	
1888 <i>Textile Manufacturer</i>	H. Koechlin	Cotton	2–4 vols	Room temp	Caustic soda, silicate of soda	3–4 days	Ageing	The cotton first passed through weak H_2SO_4 , washed and passed through hydrogen peroxide bath
1890 <i>Textile Manufacturer</i>	—	Wool	5 vols	—	Silicate of soda pH 12–13	—	Steeping	
1892 <i>Oesterreich Wollen and Leinen Industrie</i>	—	Wool pieces	$1\frac{1}{2}$ vols	—	Silicate of soda pH 12	3 times through bath on jigger—then 24 hours	Ageing	After H_2O_2 bleaching, washed with 6° Be bisulphite, then for 24 hours, passed through 1° Be HCl washed
1893 <i>Textile Manufacturer</i>	W. M. Gardner	Wool	1 vol	95° F	Ammonia pH 11	12–24 hours	Steeping	
1899 <i>Bull. Soc. Ind. de Mulhouse</i>	K. Koechlin	Cotton	0.3 vol	—	Calcined magnesia	3–6 hours	—	Bleaching carried out in Mather & Plattier at 2–3 atmos pressure. Bleaching solution consisted of 1,000 litres water, 10 kilos soap, 1 kilo calcined magnesia, 30 kilos H_2O_2
1902 <i>J. Soc. Chem. Industry</i>	C. A. Lawcott	Wool	3.5 vols	60° F	Silicate of soda pH 10.5	24 hours	Steeping	Scoured wool first immersed in 2% silicate of soda do do plus wool dried at 80° F
		Wool	do	do	do	1 hour	Steeping and ageing	
1905 <i>Textile Manufacturer</i>	—	Tussah silk	2 vols	120° F	Silicate of soda and soap	A few hours	Steeping	

Patent or Journal	Patentee or Author	Material Bleached	Strength of H_2O_2 Bath	Temperature	Alkali, etc. for Neutralising	Time of Bleaching	Type of Bath	
1909 German Patent 256,997	H. Siebold	—	—	—	—	—	—	Goods saturated with unneutralised H_2O_2 and subjected to ammonia vapour.
1911 American Silk Journal	L. J. Matis	Tussah silk	3 vols. 10 vols.	— —	Ammonia plus caustic soda pH 13 —	12 hours —	Steeping Ageing	Silk impregnated and suspended in lightly closed chamber over shallow pans of ammonia.
1915 British Patent 13,215	A. E. Garrett	Wool	1 vol.	120° F.	—	—	—	Goods after immersion in H_2O_2 bath for a few minutes are squeezed and dipped in a solution containing 4-5 c.c. of NH_3 , 4-5 gms. soap per litre at 120° F. Goods are squeezed and allowed to dry for 1-2 hours.
1921 British Patent 162,198	Kershaw	Wool, silk, etc.	1.2 vols.	Cold	Ammonia pH 10-11	16 hours	Ageing	H_2O_2 bleaching followed by soap wash and hydrosulphite bleach.
1922 J. Soc. Dyers and Colourists, May	H. Wilson	Wool	1 vol.	104-120° F.	Ammonia pH 10	12-24 hours	Steeping	
1923 British Patent 196,003	D. & G. McIntosh	Wool	—	—	—	—	Ageing	The process is continuous, the yarn being passed through the H_2O_2 bath by means of tapes, then squeezed by pressure rolls so that the weight of solution is less than the weight of dry yarn.

From the tables it will be seen that the processes can be divided into—

- Steeping processes, wherein the material is steeped in a hydrogen peroxide bleaching bath for a period of time.
- Ageing processes, wherein the material is steeped in a hydrogen peroxide bath in order to saturate it with hydrogen peroxide, the goods being then removed and allowed to dry.

Modifications of these processes are also indicated, for instance, goods bleached by the steeping process are sometimes followed by sulphur stoving or a liquid bisulphite bleach.

In the ageing process, the goods saturated with hydrogen peroxide are sometimes subjected to ammonia vapour and in other cases after the peroxide bleach has taken place the goods are given a hydrosulphite bleach.

Steeping Processes

The strength of the hydrogen peroxide bleaching bath appears to vary from $\frac{1}{2}$ volume to 5 volumes, and the temperature of bleaching from cold to 120° F., the time of bleaching varying from one hour to 24 hours. It was realised at an early stage that although the hydrogen peroxide as sold was slightly acid in order to render it stable, good bleaching results were not obtained by using the hydrogen

peroxide as such, so that it was necessary to take steps to neutralise or make alkaline the hydrogen peroxide according to the particular purpose for which it was being used. Thus ammonia, caustic soda, soda ash, lime, and silicate of soda were used to neutralise the acid in the hydrogen peroxide.

As during the period under review no mention is made of the pH values of the bleaching baths which were found to be a useful factor in bleaching (see I. E. Weber, *J. Soc. Dyers and Colourists*, July 1923, and S. R. and E. R. Trotman, *ibid.*, May 1926), an attempt at reconstructing the bleaching baths as indicated either in the patents or in the literature has been made and their pH values determined. Thus, where ammonia is used as the neutralising agent, pH values from 7 to 11 are obtained, whilst with silicate of soda baths, the pH varies from 10 to 13.

In order to increase the strength and brilliancy of the fibres Leboutoux recommends the addition of any of the following ammonium salts—perchlorate, hypochlorite, nitrate, arsenate, carbonate, oxalate, or formate.

Ageing Processes

In the ageing process the strength of the bleaching bath varied from $1\frac{1}{2}$ to 10 volumes. As above, determination of the pH of reconstructed baths gives in the case of ammonia a pH value of 7–10 and in the case of silicate of soda a pH value of 12. Ebell recommends that the goods which have been saturated with the hydrogen peroxide should be dried at a temperature of 54–63° F., whereas Fawcett recommends a temperature of 80° F.

Bleaching of Wool, Wool-Cotton, and Wool-Silk with Hydrogen Peroxide

The ideal bleach is one which will destroy the colouring matters, leaving the fibre unimpaired. Yarns or fabric of yellow, brown, or grey colour of good or poor quality are bleached successfully with hydrogen peroxide. The hydrogen peroxide bleach is more permanent than other methods of bleaching. Yarns originally yellow and grey bleached many years ago retain their whiteness and have not returned to the yellow colour which would have been the case with stoved goods. The white is a purer white than that given with sulphur dioxide. A good lofty handle, free from wiriness, is obtained with a hydrogen peroxide bleach and the goods retain their freshness during storage. As the hydrogen peroxide consists almost entirely of oxygen and water there is little to rinse out after the bleaching process. The rinsability is aided by the fact that the evolution of oxygen during the bleaching process tends to open up the yarn or fabric.

In the bleaching of wool, whether by the steeping or ageing process, the cost of bleaching is affected by the number of times the bleaching bath can be replenished. It is important that the accumulation of impurities should be kept at a minimum by employing as good a quality of bleaching materials as is possible. The water supply should be soft and preferably Zeolite softened. The particularly harmful effect of copper salts has already been indicated and care should be taken that the water does not contain traces of copper. Whilst iron, manganese, and chromium salts are not as deleterious as copper, they should also be avoided.

The writer has indicated in a previous paper that silicate of soda is preferable to ammonia for neutralising the bleaching bath. The silicate of soda referred to was "water glass" having the ratio of $Na_2O:SiO_2$ of 1:2. Sodium silicates having ratios of $1Na_2O:3\cdot2SiO_2$ and $1Na_2O:1SiO_2$, viz. metasilicate, are now available, and comment on these is of interest—

- (a) The increase of the pH value of the bath to figures greater than $pH7$ means generally increased loss of hydrogen peroxide with a 1-volume and 2-volume bath whether wool is present or not and irrespective of the ratio of $Na_2O:SiO_2$ in the silicate used.
- (b) Generally wool stabilises the bleaching bath, the difference being quite appreciable. This increased stability appears to be due to the reduction of pH number during the bleaching.
- (c) For a better bleach and economy of bath it is preferable to use a silicate of soda of the ratio $Na_2O:3\cdot2SiO_2$ rather than water glass or metasilicate.

The above conclusions were based on experiments using the three sodium silicates for neutralising the bleaching bath and was in a range of *pH* values of 7-12.

The bleached wool obtained by the above method, if of insufficient whiteness, is given a sulphur stoving or a liquid bisulphite after-treatment.

Improved Method of Bleaching

Where an enhanced white is required, excellent results can be obtained by using a hydrogen peroxide bleaching bath to which has been added pyrophosphate of soda and sodium oxalate or oxalic acid. As far as the writer is aware this is a new departure in bleaching wool and gives results obviating the need for subsequent stoving or bisulphite treatment. The method is mainly applicable to the steeping process and this combined stabiliser and neutralising agent is marketed as Stabiliser C and is recommended for use as follows—

The hydrogen peroxide bath is made up as a 1 or 2-volume bath depending upon the degree of white desired. 5½ lb. of Stabiliser C is added for every 100 gallons of the bleaching bath irrespective of the volume strength of the bath. The bleaching is carried out at a temperature of 120° F., and it will be found that less time is taken for the bleaching than is the case with baths neutralised and stabilised with silicate of soda or other reagents.

In replenishing the bath the hydrogen peroxide should be estimated by the iodine method, that is, by titrating with sodium thiosulphate to determine the iodine liberated from potassium iodide in an acid solution of the hydrogen peroxide.

The addition of further quantities of Stabiliser C is determined by the use of phenol phthalein, the bath being adjusted to faintly alkaline to this indicator.

Silks which do not lend themselves readily to a peroxide bleach where silicate of soda is added give excellent results with the addition of Stabiliser C.

Plant for Bleaching

(a) Materials for plant construction.

For the steeping process the plant is of a simple character consisting of a rectangular bleaching tank which may be made of wood, glazed brick, cast-iron, or steel with a porcelain or enamel glaze, stoneware, slate, Staybrite, or Monel metal. Cement mixed with a little silicate of soda forms a good surface for tanks, the wood of which has softened by constant use in bleaching, and baths so treated will last a very long time. From this it may be concluded that concrete or cement-lined tanks are satisfactory and this is actually the case, such baths being in use for bleaching purposes.

As the bleaching of wool and wool union goods is usually carried out at a temperature of 120° F., it is necessary to heat up the bleaching bath, and this can be done by a lead coil where silicate of soda is used as the neutralising agent, but in the case of Stabiliser C it is necessary to use a coil made of Staybrite, such coils being covered with a false bottom. In addition to such inert materials as glazed brick, slate, stoneware, Staybrite and Monel metal are recommended.

It is interesting to note, however, that an attempt to exaggerate the possible staining effect of the metals on the wool, and the effect on the hydrogen peroxide, gives the following results—

Action of Metal on Wool and H_2O_2 on Metals at 120° F. for 15 hours

Strength of bath 2 volumes; the sodium silicate has a ratio of 1:2 $Na_2O:SiO_2$.

Metal	Neutralised to <i>pH</i> 9 with	% Loss of H_2O_2 per sq. cm. of metal	Loss in mgms. of metal per sq. cm.
Brass ...	Stabiliser C	12.0	24
Brass ...	Sodium silicate	14.6	47
Aluminium	Stabiliser C	4.5	0.04
Aluminium	Sodium silicate	4.5	0.16
Staybrite	Stabiliser C	2.0	0.1
Staybrite	Sodium silicate	2.6	0.1
Monel ...	Stabiliser C	3.4	0.1
Monel ...	Sodium silicate	4.2	0.2
Lead ...	Stabiliser C	7.5	+0.1
Lead ...	Sodium silicate	7.9	—0.1

To summarise—

- (1) The highest loss of hydrogen peroxide per sq. cm. is given with brass, followed by lead, aluminium, Monel metal, and Staybrite.
- (2) Staining of the wool.
 - (a) With brass it is very bad both with silicate of soda and Stabiliser C
 - (b) With lead there is a slight stain with silicate of soda, but no visible stain with Stabiliser C.
 - (c) With aluminium there is no visible staining.
 - (d) With Monel metal there is a decided stain with silicate of soda, but no visible stain with Stabiliser C.
 - (e) With Staybrite there is, if anything, a very faint stain with silicate of soda, but no visible stain with Stabiliser C.

It is apparent from the above that Staybrite is most suitable for the making of bleaching tanks, and this has been confirmed in practice. The use of Stabiliser C minimises the possibility of stains.

(b) General methods for bleaching wool and wool union goods.

(i) The goods are scoured before bleaching and it is important that the scouring be thorough, and the goods to be bleached free from the oil used in the spinning. This point need not be laboured as every bleacher and dyer knows that bad scouring can be the cause of a good deal of trouble.

In the steeping process referred to above, a rectangular bleaching tank can be used for the bleaching of yarn, fabric, hosiery, such as socks, stockings, and finished goods. The goods after thorough scouring are immersed in a 2-volume bath prepared as follows—

For every 100 gallons of water at 120° F. add 2 gallons of 100 volume hydrogen peroxide. Add silicate of soda until the bath is neutral to phenol red as indicator. The goods to be bleached are immersed in this bath and left in overnight, usually 15 hours. The bleached goods are then removed, rinsed, blued, and stoved if necessary. The white obtained can be improved by increasing the alkalinity of the bath by the addition of more silicate of soda, phenol phthalein being used as indicator or by increasing the strength of the bath by the addition of more hydrogen peroxide. To obtain uniform bleaching it is important to standardise the method of operation for each particular quality of goods. This uniformity can be obtained by using the weight of the goods as a basis, the same strength of bath, the same quality of neutralising and stabilising reagents, and the same temperature for bleaching. In this way the possibility of uneven shades is reduced to a minimum.

The strength of the bleaching bath is determined by titration with potassium permanganate or by the iodine method as already mentioned.

A bleaching bath may be used for a period of several weeks, the further additions of hydrogen peroxide necessary to bring it back to its original strength after each bleach being determined by the permanganate method of testing.

The alkalinity of the bleaching bath is controlled by the use of suitable indicators.

The ratio of goods to liquor is approximately 1 lb. to a gallon, and as much as 400 lb. of material can be bleached in one bath.

The method of bleaching by the steeping process where Stabiliser C is used instead of silicate of soda has already been referred to.

(ii) For the bleaching of fabric of the tubular type, a winch machine is an advantage because of the ease with which it is possible to feed the fabric into the bleaching bath over the winch and off again when the bleaching is finished. Thus with a winch machine the tendency is to give more even bleaching and the time is cut down somewhat. With this machine it is easier to maintain a uniform temperature during bleaching as the fabric whilst moving mixes the liquor. The ratio of bleaching liquor to fabric is approximately $1\frac{1}{2}$ gallons of liquor per lb. of fabric. The velocity of the fabric over the winch is of the order

of 30 yards per minute. The winch may be made of Staybrite or wood with a heating coil of Staybrite. The hydrogen peroxide bleaching bath is made up as for the steeping process using either a 1 or 2-volume bath at a temperature of 120° F.

Using Stabiliser C bleaching can be done in from 3 to 6 hours depending upon the white desired. The bath is replenished along the lines indicated above.

(iii) For the bleaching of Angora yarn the same plant is recommended as for the bleaching of wool yarn. The bleaching bath, however, is made up on different lines. A 1-volume strength hydrogen peroxide bath is used and to this is added 2 lb. of sodium oxalate for every 100 gallons of the bath. Sodium pyrophosphate is then added until the bath is faintly alkaline to phenol red as indicator. The bleaching is carried out at a temperature between 80° and 100° F., but must not exceed the latter figure.

(iv) Bleaching of cream worsted and union gaberdines.

The following method is recommended after the goods have been scoured in the usual well-known manner. The plant for bleaching generally consists of a jigger with three rolls made of either Staybrite or porcelain. The trough of the jigger can be made in Staybrite or wood. It is now possible to obtain jiggers made completely from stoneware material, such as Pyroton, which is a stoneware specially prepared for withstanding changes of temperature and the action of hydrogen peroxide. The well of the trough of the jiggers should be so made as to contain only a sufficient quantity of dilute hydrogen peroxide necessary for the bleaching of the roll of pieces. A steam pipe is required in the well of the trough in order to maintain the hydrogen peroxide liquor at a temperature of 130° F. The steam pipe should be made of Staybrite and the heating is indirect. The bearings of the bottom roller, which is immersed in the hydrogen peroxide, are usually made of lignum vitæ. Pieces of an average length of 60 yards are sewn end to end, and the distance of the top rollers from the sides of the jigger and also the space to be allowed in the well of the trough will depend on the number of pieces that are to be bleached at one time. It is usual to bleach in a hydrogen peroxide bath of from 6 to 12 volume strength, depending on the degree of white required and the colour of the goods before bleaching.

Thus, if a 10-volume hydrogen peroxide bath is required then 1 gallon of 100 volume hydrogen peroxide will be diluted with 9 gallons of water to give a 10-volume strength bath. Assuming that a 60-yard piece weighs 32 lb. dry weight, and that after scouring it is nipped or hydroed so that it contains only 25% of water, we may take it that it will absorb 2-3 gallons of the peroxide liquor. Thus it will be necessary to allow for 2-3 gallons of 10 volume hydrogen peroxide for each piece on the roller.

The hydrogen peroxide bath is neutralised with silicate of soda, using phenol phthalein as indicator. The pieces after scouring and hydroing are run on to one of the rollers in the following way—The end is threaded over one top roller and under the roller immersed in the bottom of the trough and is then brought up and beamed on the second top roller. Thus, whilst beaming, the cloth takes one passage through the peroxide liquor. The cloth is run through the peroxide bath from top roller No. 1 to top roller No. 2 and vice versa until the cloth is thoroughly and uniformly saturated with the hydrogen peroxide. The roll of cloth is allowed to remain overnight whilst the bleaching takes place. To facilitate threading up and beaming wrappers should be sewn to both ends of the roll.

As an indication of the way in which the hydrogen peroxide is used up during the bleaching by the ageing process, a 14-oz. serge was taken and saturated with hydrogen peroxide of 6 volume and 12 volume strength neutralised with silicate of soda to phenol red and phenol phthalein respectively. From graphs which were plotted showing the hydrogen peroxide content of the serge at different times during drying the following figures were obtained—

is used for washing and deposits free fats, which are apt to become rancid and objectionable.

(vi) Felted wool hoods are bleached with hydrogen peroxide. In the processing of the hoods they are felted with sulphuric acid and therefore are in an acid state when ready for bleaching. This acidity must be neutralised by first soaking them in a 1% soda ash solution for $\frac{1}{2}$ hour in the cold. Squeeze the hoods through rollers and immerse for $\frac{1}{2}$ hour in a 10-volumes strength hydrogen peroxide bleaching bath which has been neutralised with silicate of soda, using phenol phthalein as indicator. The temperature of the bleaching bath should be maintained at 120° F. The hoods are again passed through rollers to squeeze out excess hydrogen peroxide and dried at a temperature of 80° F. The results are not so good when drying is carried out at higher temperatures. As in other cases the bath is replenished for successive bleaches.

(vii) Bleaching of wool-art silk mixtures.

Wool knitting yarns with a viscose silk thread, hose of artificial silk with wool heel, toe, and top can be bleached by the methods already given for the bleaching of wool by the steeping process. Plated wool and artificial silk fabric can be bleached satisfactorily by the method already given for the bleaching of wool by means of a winch.

Some General Observations

(a) In connection with the bleaching of wool the following should be noted—In the hosiery trade it is customary to render the goods unshrinkable before bleaching and this is done by means of sodium hypochlorite and hydrochloric acid, any excess chlorine being removed by a bisulphite treatment. The goods after such treatment usually contain free acid and it is necessary to make allowance for this by either neutralising before bleaching or adding extra alkali to the bleaching bath. This also applies to hydrogen peroxide bleaching of carbonised wool and blankets which have been milled in an acid medium.

(b) Reference has already been made to the possibility of the staining of wool by metals. The most general stains are iron, copper, and lead. It is better to prevent staining as it is generally more difficult to deal with the stain once it is formed.

Iron stains can be readily detected by spotting with either an alkali ferrocyanide or an alkali thiocyanate, and can usually be removed by either oxalic acid or hydrochloric acid.

The lead stain is usually very slight, but may be more pronounced where the hydrogen peroxide bleach is followed by subsequent treatment, for example, with a bisulphite or a hydrosulphite. Such stains may be temporarily removed by a subsequent weak hydrogen peroxide treatment.

Copper stains are usually accompanied by holes in the fabric; they may be detected by the use of sodium diethyl dithio carbamate.

In the spinning of yarn and in the knitting of fabric particular care should be taken to prevent oil containing finely-divided copper from the brass bearings or any other brass or copper parts of the machine coming into contact with the material. Such oil stains containing finely-divided metal will, owing to its vigorous reaction with the hydrogen peroxide, cause destruction of the wool fibre. Other brown stains which may occur are due to local excess of alkali and can be detected by the use of a suitable indicator such as the B.D.H. 4-11 Indicator. In detecting stains it is important to spot a portion of the unstained material at the same time as the stained portion.

(c) To those familiar with hydrogen peroxide bleaching there is a tradition that in stormy or thundery weather peroxide bleaching baths may "go off." There is no evidence that such decomposition of the hydrogen peroxide is due to atmospheric disturbances. Usually thundery and humid weather go together and tend to produce conditions which encourage the growth of bacteria

in scoured yarn or fabric, especially when they are allowed to lie in a damp condition for an undue length of time.

Wool, containing bacteria, when immersed in the bleaching bath causes rapid decomposition of the hydrogen peroxide, although the bath was perfectly stable before the addition of the wool. Under these conditions no bleaching of the yarn takes place and delicate materials may be damaged. Therefore the tradition that in stormy and thundery weather hydrogen peroxide bleaching baths may "go off" is probably due to bacterial activity causing decomposition of the hydrogen peroxide.

Whilst this trouble rarely occurs it is possible to overcome it by passing the yarn through a weak sodium hypochlorite bath which need not contain more than 40 parts per million of available chlorine. A satisfactory bleaching bath, to which has been added wool containing bacteria may lose 59% of its original strength in a period of one hour, after giving the wool a preliminary treatment with the weak hypochlorite the loss in strength of the bleaching bath is reduced to the order of 4.6% over a period of four hours, a striking difference.

An analogous phenomena may occur where rollers covered with wool slubbing are used to squeeze goods saturated with hydrogen peroxide for bleaching by the ageing process. Such a wool slubbing may after long use contain bacteria which are printed on to the goods during their passage through the rollers, causing local decomposition of the hydrogen peroxide with consequent uneven bleaching. This trouble can be obviated by using slubbing which has been given a preliminary hypochlorite treatment.

Different types of bacillus have been identified from contaminated wool, amongst which are—

- b. Subtilis.*
- b. Fusiformis.*
- b. Brevis.*
- b. Megatherium.*

Pure cultures of these bacilli were obtained and their effect on hydrogen peroxide bleaching baths investigated. The results confirmed the fact that rapid decomposition is possible in the presence of such bacteria. It is possible to use a quick and simple method of detecting whether wool is heavily contaminated with bacteria. Take three beakers each containing 500 c.c. of a freshly prepared bleaching bath. One of the beakers is to be used as a blank, to the second beaker should be added some of the doubtful wool, and to the third beaker an equal quantity of wool which has been previously immersed in a weak sodium hypochlorite solution, obtained by adding four drops of sodium hypochlorite (14/15% available chlorine) to 500 c.c. of water. With contaminated wool rapid decomposition of the hydrogen peroxide takes place, this decomposition being shown by a marked effervescence. Estimations of hydrogen peroxide strength by the permanganate method indicates that the blank and the beaker containing the hypochlorite treated wool have sustained practically no loss, whereas the other beaker shows a very marked decrease in strength.

Bleaching of Silk with Hydrogen Peroxide

Before bleaching silk with hydrogen peroxide it is necessary to remove the sericin by degumming. There are on the market specially prepared **degumming** materials, which usually consist of sodium silicate and a sulphonated castor oil. Generally, however, olive oil soap with or without the addition of alkalis is used.

(a) Pure silk stockings, with or without cotton tops and heels, are bleached after first degumming in a 10% olive oil soap. It is preferable to place the stockings in net bags and excellent results are obtained in Monel metal rotary machines. Thus 200 dozen of these stockings can be bleached in 300 gallons of a 1-volume bath, to which has been added 20 lb. of silicate of soda. The temperature at the commencement of the bleaching is 165° F. and at the finish 195° F. Good results are obtained by bleaching for two hours.

Where it is desired to degum and bleach in the same bath the following methods are suitable.

For 200 dozen silk stockings, with or without cotton tops and heels, use 300 gallons of a 1-volume strength hydrogen peroxide, 25 lb. of olive oil soap, 2 lb. sodium silicate. The temperature at the commencement of bleaching is 165° F. and at the finish 195° F. Monel metal rotary machines can again be used and the time of bleaching is one hour.

Instead of olive oil soap, sulphonated castor oil can be used. For 600 lb. of pure silk stockings with mercerised tops and feet, 300 gallons of a 1-volume strength bath should be used, to which is added 20 lb. of sodium silicate and 6 lb. of sulphonated castor oil. Commence bleaching at 165° F., bring to 195° F. as quickly as possible, and maintain at this temperature for one hour. After bleaching the goods should be well rinsed. These stockings are also bleached in net bags in Monel metal machines. When using sodium silicate and sulphonated castor oil, care should be taken that the materials used are of good quality, otherwise there is the possibility of soap-gum specks separating out on to the stockings and the machine cage.

(b) Hose consisting of artificial silk on cotton or artificial silk and cotton can be bleached in the following bath.

For 200 dozen stockings use 300 gallons of a 1-volume strength bath, 4 lb. of olive oil soap, and 1½ lb. of sodium silicate. The bleaching bath is 165° F. at the commencement and 195° F. at the finish, the bleaching taking one hour.

(c) Pure silk crêpe pieces are degummed and bleached in winch machines. 300 gallons of liquor is used for approximately 100 lb. of crêpe silk. The silk is degummed with olive oil soap, 30% of the weight of the goods being used. The degumming bath is maintained at a temperature of 190° F. for two to three hours, depending upon the degree of degumming and handle required; the goods are then washed off thoroughly. The bleaching with hydrogen peroxide is carried out in the same winch and a 1½-volume strength bath is used. Sodium silicate is added to the bath until just alkaline to phenol phthalein as indicator. The temperature of the bleaching bath is brought up to 160° F. and is maintained at this temperature for approximately two hours to complete the bleach. The goods are washed off and dried.

Bleaching of Cotton with Hydrogen Peroxide

In 1888 Horace Koechlin suggested the use of hydrogen peroxide for the bleaching of cotton. The cotton was first passed through a weak sulphuric acid solution, washed off, and then passed through a hydrogen peroxide bath at room temperature of approximately 2.4 volumes strength, to which had been added caustic soda and silicate of soda. The saturated cotton was placed on one side for three to four days, so that bleaching could take place. In 1889 Koechlin further suggested the use of a Mather & Platt kier for the bleaching of cotton with hydrogen peroxide at two to three atmospheres pressure. Calcined magnesia and soap were added to the bleaching liquor. The recent and extensive developments in the bleaching of cotton by means of hydrogen peroxide include the use of such materials as caustic soda, silicate of soda, soda ash, pyrophosphate of soda, with the addition of pine oil, sulphonated fatty alcohols and other wetting-out agents which help penetration.

The development in the bleaching of cotton with hydrogen peroxide has become a possibility owing to the improvement in the quality of the latter, the advance in the technique of hydrogen peroxide bleaching and the use by suitable treatment of iron kiers, thus obviating the necessity for the replacement of existing plant. Rapid strides have taken place in the bleaching of American cotton, as this is easier to bleach than the Egyptian variety. It is necessary to give some cottons a preliminary boil. Generally a single hydrogen peroxide bleach is sufficient to give the desired white. On the other hand, it is sometimes necessary to follow the preliminary boil with two peroxide baths, the first being of a lower

strength than the second. This is especially the case with Egyptian cotton, the first bath functioning as a desizing bath.

Cotton is bleached by the hydrogen peroxide process on an extensive scale, both for whites and subsequent dyeing and printing.

Cotton so bleached, whether in the form of yarn, piece goods, or knitted fabrics (as samples shown) have a fluidity less than five as determined by the method of the Fabrics Research Committee (1932 report) and therefore comes within Clause 1, which comprises very mildly prepared (scoured or scoured and bleached) cottons. Normal scoured and bleached cottons for textiles and unbleached pulps are classified as having a fluidity of five to ten (Clause 2).

The cotton must be clear, pure, free from impurities and contamination and of a good white colour. It is possible to compare the whiteness of different batches by taking four layers of the material in the wet state. The bleached cotton must also have good absorptive properties with a uniform affinity for the dyestuffs, so that in colour printing the dye is absorbed satisfactorily by the fabric.

Cotton bleached with hydrogen peroxide fulfils these requirements.

Plant and Methods for Bleaching Cotton

(a) Where it is impossible to bleach single fine knitting yarns in the skein form, these are bleached in package machines, whereby the yarn is kept straight and unbroken and the packages are convenient to handle. Machines of the Obermeyer and Franklin type are used. The machines carry varying loads from 250–500 lb., depending upon the size of the machine and the number of spindles. The spindle of the Obermeyer machine is perforated and is made of Monel metal. The body of the machine, however, is made of iron. Such machines are occasionally boiled out with silicate of soda, but otherwise no lining is applied to the machine. Following the usual preliminary boil, the yarn is given a peroxide bleach just below the boil for two hours. As is usual with these machines the flow of liquor is reversed automatically. The peroxide bleaching bath is approximately $\frac{1}{2}$ to $\frac{3}{4}$ volumes strength and contains both caustic and sodium silicate which is present in a ratio to give approximately sodium metasilicate. The bath has a pH of 11.5. After bleaching the cotton is given the necessary rinse. Thus the whole of the operations can be carried out in the same machine, avoiding unnecessary handling.

The Franklin Process Co., of Providence, Rhode Island, U.S.A., are operating their machines on a large scale for the bleaching of yarn with hydrogen peroxide. This machine, as is well known, has the following novel feature. The yarn is wound to form a package on a nickeline or German silver spiral spring covered with knit fabric, which prevents the yarn from falling between the coils of the spring. The spiral spring is thus compressible lengthwise. Machines made of aluminium and iron are used. The writer has seen these machines in operation and a 500-lb. aluminium machine had been working for about five years. A typical bleaching liquor for a 500-lb. machine is made up as follows—

- 500 gallons of water;
- 40 lb. silicate of soda;
- 5 lb. caustic soda;
- 18 lb. 100 volumes hydrogen peroxide.

Where an aluminium machine is used the silicate of soda is added to the water first, followed by the caustic soda; with the iron machine the caustic soda and silicate of soda are added together. The packages are loaded into the machine; it is then filled up with the water containing the sodium silicate and caustic soda. The liquor is brought up to a temperature of 140° F., the hydrogen peroxide added, and the temperature raised to 180° F. The bleaching liquor is maintained at this temperature for 1½ hours and then for a further half hour at 200° F. The yarn is then well washed and tinted, the total time of the operation taking four hours. The flow of liquor is reversed every 10 minutes, the rate of flow being 1 U.S. gallon per minute per lb. of yarn. It should be noted that the bleaching

is not carried out under steam pressure, the pressure being due to the resistance of the yarn to the liquor. The packages, after bleaching or bleaching and dyeing, are hydroed and dried in a tray drier by means of hot air. A sample of 100 single mule spun yarn, bleached and dyed by the above method, is shown.

One man can operate three machines, and a 1,000-lb. machine requires 25 h.p. to run it. Yarns bleached or bleached and dyed by the Obermeyer and Franklin machines have fluidity figures of 2 to 2½.

In the United States cotton yarn is being bleached on the beam in the Brantwood type of machine, using hydrogen peroxide as the bleaching agent.

(b) Cotton piece goods, muslin and gauze fabrics, viscose and cotton mixtures, coarser counts of yarns in skein form, are bleached in open-top kiers with centrifugal pump and multitubular heater. Although, as mentioned, iron package machines are being used for bleaching without giving them a protective lining, the following has been found to be a satisfactory method of lining a kier to eliminate the possibility of staining the goods or decomposition of the hydrogen peroxide when the kier is being used for the first time.

Four parts of Portland cement, one part of burnt lime, one part of magnesium oxide, is made into a thin paste with a dilute solution of silicate of soda of approximately 20° Tw. and painted or sprayed on to the inside of the kier. Care should be taken to see that the surface of the kier is well covered. The lining is allowed to dry for 24 hours, sprayed with a 20° Tw. solution of sodium silicate, and allowed to dry. The surface of the kier should then be painted with a 5% hydrochloric acid solution, and after drying the kier is ready for use.

Care should be taken when piling the goods into the kier to prevent channeling, and the open-top kier is particularly suitable for "mechanical" piling. In the case of viscose and cotton mixtures, these should be packed between cotton goods at the top and bottom of the kier, so as to avoid an undue strain on the silk fabric. The goods are given the usual preliminary open boil and washed off. For the bleaching bath the ratio of goods to liquor is of the order of 1:2 or 1:3, depending upon the type of goods to be bleached. The volume strength of the bath in the same way varies from ¾ to 1 volume strength. As already stated, the sodium silicate and caustic soda are added to the bleaching bath to give a ratio of $\text{Na}_2\text{O}:\text{SiO}_2$ of approximately 1:1. Small quantities of wetting-out agents are often added to aid penetration.

The liquor is raised to the boil and bleaching takes place in approximately 6-7 hours. By this time the bath is exhausted and the goods are rinsed off and are ready for the usual finishing processes, or for dyeing and printing. Quantities from 1,000 to 6,000 lb. can be bleached in a kier at one time.

As already explained in the bleaching of wool, the presence of copper is deleterious. As copper salts are used in the after-treatment of direct cotton colours to increase their fastness to light or washing, and also with aniline black dyeing, striped materials in which these dyestuffs have been used should not be bleached with hydrogen peroxide, as they are liable to damage. Thus in the same way a cuprammonium artificial silk should be avoided.

(c) Cotton knitted tubular fabrics are bleached in winch machines made of either wood, Monel metal, or Staybrite, as described under the bleaching of woollen tubular fabrics. A ¾-volume strength bath is sufficient, but the alkalinity of the bath is much higher than is the case for wool. Caustic soda and sodium silicate is added to the bath to give a pH of 11.5 to 12, and the bleaching is carried out at the boil for a period of about 2 hours. In this way a fabric is produced with a softer finish and with nap raising qualities superior to that obtainable by the chlorine bleach.

The higher cost of chemicals in the hydrogen peroxide bleach is compensated for by the saving in labour, handling, and the reduced number of operations. Thus the final cost compares very favourably with the cost of chlorine bleaching.

Whilst this paper deals with the bleaching of cotton, wool, and silk, or combinations of these fibres, hydrogen peroxide is also used in the bleaching of feathers, furs, straw, sheepskins, bone, ivory, parchment, gelatine, glue, isinglass, fats, and many other materials.

DISCUSSION

The Chairman, opening the discussion, said that Mr. Weber had covered a wide field regarding the use of a substance of which chemists knew relatively little. He wished to know something more of the general properties of hydrogen peroxide; for example, why was it so sensitive to slight changes in pH values? There was also the question of its sensitivity to metals which was serious from the point of view of its general utilisation. Its action appeared to be difficult to control.

Replying to the Chairman, Mr. Weber remarked that whilst hydrogen peroxide has been used in the textile field for about fifty years its applications were increasing with the advance in technical knowledge, *e.g.* the Chairman's reference to the sensitivity of metals to hydrogen peroxide was met by the use of staybrite and monel metal, and in the future other metals may be discovered which will be equally satisfactory. The question of control was a relative one; in order to obtain satisfactory results from any technical process nowadays it was necessary to have scientific control and this was no more difficult in the case of hydrogen peroxide than with other bleaching processes. The advances made in recent years in hydrogen peroxide bleaching made it possible to carry out the process on simple lines. The sensitiveness of the hydrogen peroxide bath to pH values was not a disadvantage as it enabled one to change the conditions for bleaching to meet the various types of materials to be bleached. By suitably buffering the hydrogen peroxide bath it was possible to maintain a uniform pH during the time of bleaching.

Mr. W. Kershaw said that some two years ago there had been an abundance of processes and patents on the market in connection with this substance, which mainly emanated from the United States and Germany. A German company had sent a representative to their works for large scale trials which had not been a success. These trials were first conducted at a Scottish branch of the Association and due precautions were taken in suitably lining the kiers employed. Unfortunately an examination of the water supply was not conducted primarily and, as it was found later to contain traces of copper, it had been detrimental. Peroxide seemed to be much more sensitive to copper than was sodium hypochlorite. Another point of interest was the question of absorbency; it was claimed that cotton goods bleached with peroxide were definitely more absorbent. Samples stored away for a period of time were found to have lost a good deal of absorbency. He thanked the speaker for his useful hints in the use of Stabiliser C.

Mr. Weber, in reply, said that in regard to the use of peroxide with dyestuffs containing copper they had been very cautious. He looked forward to the time when the difficulties referred to by Mr. Kershaw would be overcome and he could assert that great strides were being made in the use of peroxide.

Mr. Harrison asked if Stabiliser C was of little or no use for cotton bleaching.

Mr. Weber replied that whilst for wool and silk excellent results were obtained with Stabiliser C, the work on cotton bleaching with this stabiliser had not progressed sufficiently to give a definite opinion.

Mr. Butterworth stated that in the combined chlorine-peroxide bleach for linen he had found the latter very satisfactory. It was very interesting to note that the viscosity test of the linen was unchanged after the peroxide bleach.

Replying to further questions, Mr. Weber said that acetanilide had been used as a stabiliser but it had the objection of forming acetic acid and aniline, the latter discolouring the hydrogen peroxide. He preferred the use of other stabilisers to acetanilide. In his opinion a pH of 10 was safe and satisfactory, but for Angora rabbit wool a pH of 8.5 was preferable and a temperature of 80–100° F.

SOME FAULTS IN FINISHED FABRICS

By PERCY BEAN, Ph.D., M.Sc.

Chairman—Mr. G. B. SLATER

In the course of practice as a textile chemist and consultant one meets with a very large variety of faults in cloths, some readily explainable and others requiring much thought and experiment. In this paper I propose to discuss a number of faults which affect the quality of finished fabrics. These include some examples of damage arising in the actual finishing operations, but the majority are faults which arise at earlier stages of processing. As may be imagined, there are hundreds of different faults which may affect the ultimate quality of cloths and, in order to traverse the whole ground, it will be necessary to deal with each section very briefly. Any enlargement of a subject may be dealt with in discussion.

It will be simplest to start with the early processes and describe faults arising at each stage of manufacture up to the finished cloth. In order to keep the subject within reasonable dimensions I shall confine my remarks to fabrics made of cotton and rayon.

Troubles commence with the cotton itself and the preparation of yarn. Amongst these are faults caused by the introduction of so-called "dead cotton" into the yarn. Small masses of "dead cotton" may pass unnoticed through cloth manufacture and bleaching only to cause trouble by appearing as light or white specks after dyeing or printing. This effect is due to the poor affinity of dead cotton for cotton dyestuffs, the degree of visible damage varying with the amount of dead cotton present, the depth and shade of the dyeing, the type of colouring matter, and to some extent upon the finish applied. The patterns which I produce will speak for themselves.

Different types of cotton may vary in colour. I have some excellent examples which show the effect of accidental mixing of two shades of cotton in one piece of cloth. One of these is a cloth in which were mixed deliveries of weft from two different spinners. The counts, picks per inch, etc., are the same for each lot of yarn, but the colours of the cottons differ materially and give to the grey cloth a markedly striped appearance. The effect is sufficient to spoil the cloth in the grey state, although the difference in shade is removed in bleaching. There is a danger of such a fabric showing bars, when dyed, owing to the fact that different cottons may have different dyeing affinities. A fault of this kind may be due to the carelessness of the spinner or, as was the case in the example produced, by that of the manufacturer.

From bars of the type described it is a short step to weft bars produced in the loom by such means as uneven packing of the picks of weft. Such bars are not always conspicuous in the grey cloth, but they are nearly always distinct when the cloth has been dyed and finished. The cloth structure, colour, and finish modify or accentuate the fault in various degrees. Somewhat similar faults may be produced by wrong tensioning of the yarn, by means of the shuttles, variable winding tension on pirns, and so on.

Various cloudy effects, which render finished cloths shabby in appearance, may be traced to the effects of irregularly spun yarn containing thick and thin places. According to the disposition of these variations, the cloth may possess a patchy and streaky appearance either warp-way or weft-way. An example of such a cloth, after dyeing and finishing, shows the effect of dark streaks on a lighter ground. This is due to the difference between the reflection of light from the thick and thin places and not to an actual difference in the shade of the yarns. This type of defect is particularly serious in the case of satteens and similar cloths. Another source of faults, which in some ways resemble the last, is the mixing of yarns of different counts or turns per inch in the same cloth. In this case there is little hope of hiding the fault by bleaching and dyeing, because the

regular reflection of light from the cloth surface is broken. Similar effects may be produced by irregularities in the warp.

No woven cloth is perfect, but many faults are avoidable. For instance, faults arise from irregular spacing of the warp by wrongly spaced or bent reeds, wrong warp tension, etc. In addition to such faults, one meets the results of accidents such as broken threads, temple marks, damaged threads, and these are often apparent only after later processing. Sometimes the finisher is called upon to take the blame for such mistakes when he is innocent.

An interesting set of examples is one where certain fancy cloths woven with coloured weft showed faint bars. In these there was a small difference of shade between the yarns from different pirns, and it was found that the yarns were from two dyeings with the same dyestuff.

In addition to mechanical faults in cloths, which are more or less accentuated by dyeing and finishing, there are many forms of damage to which cloths are liable in the form of stains. Amongst the examples I quote are stains due to oil from the spinning mill, sometimes accompanied by iron stains. These oily stains may be sufficient to spoil the grey cloth; they frequently remain after bleaching, and they often produce resistant places and stains after dyeing and finishing. Oil and iron stains may be present on warp yarns from dropping of the staining material from shafting on to warps, or from splashing from various lubricated parts of the loom, etc. Other types of oil stains appear on woven cloth from similar sources. In this case they are often more easily seen than when on single threads, and this gives rise to another defect which is detrimental to the dyeing and finishing of cloth. That is, the attempts made by the weavers to remove stains. It is a common practice to attempt the removal of oil stains by means of various soaps, solvents, and a multitude of "oil-stain removers" which are hawked about the mills. In the majority of cases the attempt not only leaves most of the oil stain but increases damage by leaving a friction mark or distortion. The rubbed place may not be detrimental in the grey or bleached cloth, but slight rubbing up of the cloth often causes such a difference in light reflection from the surface of a dyed cloth that a distinct appearance of discolouration may be found. This is generally more serious in the case of faced cloths like sateens, where minor distortions may cause major defects. All rubbing of stained places should be avoided. If the stain is readily removable by dropping on to the cloth a harmless solvent or emulsifier which will assist in removal of the stain during scouring, by all means let that be done, but it is often more satisfactory to leave stain removal to the bleacher, who has better facilities for this sort of thing. One of the penalties of employing soap and water for removal of stains is sometimes a patch of iron stain from the rusting of metal parts of the loom with which the damp cloth comes into contact. A favourite spot for washing out stains is the front rest of the loom, with the result that an iron stain appears across the cloth. Under such circumstances it is not unusual for mildew to appear at the treated place in company with iron.

Whilst discussing the subject of stain removal, examples may well be quoted of the dangers of attempts to remove iron stains by means of oxalic acid or agents containing the acid or its salts. These substances may apparently remove the stains and leave the cloth in a clean condition, but more serious damage may result, as my patterns will show. When the oxalic acid is dried into the cloth it may produce tenderness and perhaps rupture of the fabric in later processes. Alternatively, or in addition, the dyeing properties of the cotton at the affected places may be so changed that serious stains are produced in dyeing.

The mildew stains, which I mentioned as a possible result of washing out stains, may be removed in bleaching, or they may become so serious as to attack the fibre and cause damages visible after bleaching or dyeing. This matter will be considered more fully later.

Sizing of warps is a source of many faults to be found in finished cloths. For example, there is the application of improper mixings which result in grey cloths being wrong in finish, or otherwise mechanically unsatisfactory. Again, there is the use of unsuitable ingredients for a given purpose. For example, zinc and magnesium chlorides may be put into cloths which are to be singed or undergo other heat treatments, with the result that the cloth becomes tendered owing to the decomposition of the chlorides within it.

It sometimes happens that the nature and amount of fatty softener used in sizing is such that it causes damage. An example may be recorded in which the warp was overloaded with Japanese tallow and which was hot calendered subsequently in the grey state. This caused the fatty matter to be displaced and solid masses were visible when cold. Similar effects have occurred on dyed and finished cloths in which excessive fat or wax was used, as examples show. The presence of mineral wax in the size wax may lead to damage in dyeing and finishing. The wax may be spread or localised and act as a resist to dyestuffs, because it is not likely to be removed by scouring in the usual manner.

Wrong manipulation in sizing and unsuitable mixings frequently lead to mildew in cloth, and this is a serious defect. The different ways in which mildew may be produced are many, and I intend to produce only a few examples. One of the commonest causes is the leaving of excessive moisture in the warp, and this may result in mildew on the beam, in the weaving shed, or later. Another cause is the employment of a deliquescent substance such as glycerine or magnesium chloride without a preservative or with insufficient preservative. According to the severity of the attack, the cloth may be affected in its dyeing properties, so that it is irregular when dyed or finished. Mildew is generally of more consequence in cloths which are shipped in the grey state. It may arise as mentioned previously, or by packing the cloth in a damp condition, by storing under wrong conditions and by various outside agencies. The result may be slight staining or damage of such severity that the cloth is reduced to a mass of discoloured pulp. In cloths for bleaching and dyeing, the growth is usually checked by the bleaching before it becomes sufficiently severe to cause appreciable tendering.

In cloths containing thick borders, mildew often occurs owing to excess moisture being left in the border warp-yarns. This may be avoided by employing suitable arrangements so that the border is dried as much as the rest of the warp. The border yarns are often run over the drying cylinders on top of the other warp, so that the drying is poor. An excellent example of damage created in this way is a sample where the border is dyed with lead chromate whose colour has been changed by the mildew.

Another example of the attack on colours by mildew is introduced appropriately at this point, although the mildew was not caused by wrong sizing. This is a blue cloth, coloured with Ultramarine. The acid developed by the mildew has been sufficient to attack the colour and discharge it in spots. A somewhat similar example is one where a cloth was dyed with a direct colour of the Congo Red type, and in this case the acid developed has changed the red shade to a blue.

The various processes involved in bleaching lead to many forms of faults in finished cloths, and I shall illustrate a few of these. They include damage arising from improper singeing of the grey cloth, for example, excessive singeing along one side of a piece owing to a faulty machine. The effect of this is either tendering or changing the dyeing properties of part of the cloth, so that it dyes less deeply along one side.

Damages from the kiers may be caused, for example, by not expelling air from closed kiers and so causing local oxidation of the cloth with consequent alteration of dyeing properties and of strength. Holes may be caused by steam bursting its way through the cloth and by having insufficient liquor in lime-boiling processes with consequent tendering, and stains may be caused in various ways.

When cloths are insufficiently scoured they may be left in such a condition that, although well whitened in the bleaching process, they discolour eventually, either in subsequent laundering or on ageing. This defect is frequently found in thick fabrics which are used for white canvas shoes.

Lead stains have been traced to the kier in some cases. In one example the cause was a red-lead packing which had been used for a pump. The lead compound had been dissolved by the alkaline lye and had been transferred to the cloth. The stains only became apparent after some time, when they had been exposed to the darkening effect of hydrogen sulphide in the atmosphere.

When lime boiling is employed as a detergent, it may be the cause of stains composed of the lime compounds of fatty acids or of calcium sulphate where sulphuric acid is used for souring. These may appear as yellowish stains on bleached cloth or may act as resists in dyeing and finishing. Satisfactory washing arrangements and proper souring should prevent this form of damage.

Many faults arise in the actual bleaching with hypochlorites or other oxidising agents. If the bleaching agent is applied in too concentrated a form or not completely dissolved, there is a danger of tendering the cotton and producing oxycellulose. The cloth may be tendered generally or locally and have its dyeing properties altered. Uneven dyeing or tendering may be the result of undue exposure of parts of the cloth to the air when impregnated with "chemic," or by allowing uneven drying before washing. If all traces of "chemic" be not removed by washing, the chemic-laden cloth may be attacked by the vigorous generation of chlorine when it is passed into acid. On the other hand, severe damage may arise if the washing and souring were inadequate or irregular and traces of oxidising agent be left in the cloth. Gradual or rapid tendering may then occur on ageing, or the cloth may become tender in calendering or drying. Incomplete removal of chemicals is found most often with thick cloths, because of the difficulty of penetrating them uniformly and thoroughly.

The souring process leads to frequent damage. If the acid be too strong there may be tendering, but the commonest form of damage is the leaving of traces of acid through inadequate washing. Tendering may result on drying the cloth or on ageing, and the dyeings on this cloth may be irregular. Local damage may be caused by allowing portions of the cloth to become dry by exposure whilst they contain acid. The result of acid attack is somewhat similar in its effects upon strength and dyeing as in the case of over-oxidation.

Casual damages of various kinds may arise in the bleachworks. Examples may be quoted of wood stains from the dropping of condensed steam from wood-work and by cloth coming into contact with wood under certain conditions. Such stains may be difficult to remove and may act as mordants in certain dyeing processes, so that the staining is emphasised. Lead stains may arise from paint being splashed on to the cloth or coming into contact with it in other ways, and iron stains may be caused by drippings or contact with rusty machine parts. Cloths may be splashed with acids, chemic, alkalis, etc. resulting in tendered places or places where the dyeing properties are affected. Mercerised patches may be found owing to strong caustic soda being splashed on to the cloth. One most interesting, and fortunately rare, example of a fault having the character of a mercerised patch is one which showed a dark place when dyed. The explanation was not readily found until it was observed that the weaver who had made the cloth was in the habit of spitting, either on the floor or on his cloth. The dried spittle had exerted an effect like that of a splash of mercerising liquor and had changed the affinity of the cloth for the dye.

Mechanical damages frequently arise in the bleachcroft. Common damages are distortions and rubbing of the cloth face by chipped pot-eyes and the like, and the result may be an apparent change of shade at the damaged places when dyed, or a faulty appearance when finished. Wrong manipulation, as by running some types of cloth in the rope-form instead of in open width, may result in

distortion and damage. Threads may be damaged or broken by excessive tension, and cuts may be made by passage of the cloth between badly adjusted nip rollers or cracked pot-eyes, or by hard foreign bodies becoming embedded in calender bowls and cutting the cloth at regular intervals, etc.

Many forms of damage take place in the mercerising of cotton. Working under wrong conditions may result in the bleeding and marking-off of colours in woven coloured goods, although this type of damage is more frequently caused by the use of unsuitable types of dyestuffs by the dyer or manufacturer. It is often found that yarns dyed with different colouring matters are mixed in a cloth, some having a satisfactory resistance to mercerising and others being of a type which marks-off or bleeds readily. This may be the result of carelessness or ignorance on the part of the manufacturer and sometimes that of the dyer. I have many examples of this class of fault. One of these involved several shades of check-striped voiles woven with coloured warp and weft stripes. In nearly every case in this series the warp was dyed with a fast colour, either vat, sulphide, or developed primuline colour, whilst the weft yarn was dyed with unsuitable direct colours which would not stand mercerising without damage. The result of this carelessness is visible in the examples.

Irregular mercerising is very common, especially with uneven cloths where thick and thin places in the yarns, etc., affect the even penetration of the mercerising liquor. On occasion traces of acid have been found in mercerised cloth from the souring bath, but damage from this cause is rare, because it is a common practice to sandwich the mercerising between two scouring operations and to omit souring.

Mechanical faults often occur owing to excessive tension during mercerising, and I have seen carelessly-handled cloth split from one end of the machine to the other by applying too much tension to the weft. Warp and weft threads are often found broken after mercerising, sometimes owing to excessive tension in the processing and sometimes owing to defects in the cloths, such as tight threads and damaged threads. The merceriser is generally blamed for these, but it is often possible to trace the damage to manufacture or other earlier processes.

As many types of damage may arise in the dyehouse as in the bleachcroft. They are too numerous for a discussion in full, and only a few of them can be dealt with here. Frequent damage is caused by undissolved specks of dyestuffs or air-borne specks. Careless manipulation may result in "ended" pieces where the shade varies from the middle to the ends of the piece, and this may be the result of wrongly feeding the colour to the dyebath, particularly where colours are used which have a strong affinity for the material. Wrong manipulation may result in warp-way streaks of irregular colour, for instance, by creasing and having crooked batches. Streaky dyeings may be produced easily when dyeing on a spiral machine, particularly with a thick cloth which is not readily penetrated, and poor penetration is a very common fault, whereby only the outside portions of the threads are coloured and the interlacings of the warp and weft show light places. Streaky and inferior dyeings are fairly common where a mixture of dyestuffs is used to produce a desired shade, and one cause is the mixing of dyes having different degrees of affinity for cotton. This defect is generally more pronounced on rayon than on cotton.

Yarn dyeing is a source of many troubles. Cop dyed yarns often suffer from irregular penetration which may result in a cloudy effect in the cloth owing to short lengths of yarn varying in shade. Slight variations in shade from cop to cop may not be very noticeable until woven into the cloth, when they may show as strongly marked bars. Occasionally trouble is caused by a dyer supplying a certain dyeing which is satisfactory and in a subsequent delivery, by accident or carelessness, supplying the same yarn without having cleared it properly or otherwise attained the maximum fastness of the dyeing. Examples of this are often found

amongst vat-dyed and insoluble azo colours which mark-off when they ought to be of reasonable fastness. In the case of vat dyestuffs applied on the jig, the edges of the cloth are sometimes dyed more deeply owing to the batch being run unevenly and so allowing greater air-oxidation at the edges.

Space will not allow a full discussion of faults which arise in Aniline Black dyeings. There are a number of typical examples amongst my patterns showing tendering from the oxidising agents employed in the dyeing process. Sulphide blacks are also a class which may cause tendering of cotton. This is caused by the generation of acid by the dyestuff on ageing. The fault is now not so common, because the dyer generally takes the precaution of adding to the cloth a substance, such as sodium acetate, which will neutralise any acid which develops.

A particularly interesting problem is the action of certain vat dyestuffs which, on exposure of the dyeings to light appear to generate an oxidising action on the cotton sufficient to cause tendering. A considerable amount of work has been carried out on this problem by Mr. F. Scholefield, who will probably discuss the matter in detail at this conference.

Many of the faults found in cloths may be attributed to those who handle the cloth before the dyer, but the dyer does produce his full quota of faults. Amongst a few examples I may quote that of a black-dyed cloth which was rubber-proofed and made into raincoats. After being in contact with rain a greyish marking appeared in various places. This was composed of small crystals of sodium sulphate which concentrated in certain places, owing to the solvent action of the rain, and crystallised on drying. The dyer had not washed off his cloth sufficiently after dyeing. The fault was put right by soaking the coats in several changes of water and by washing subsequent dyeings in a better way.

A considerable variety of faults may be produced in the finishing processes. Mechanical faults are of frequent occurrence. For instance, damage may arise from over-stretching on stenters or in other processes. Cuts may be produced by the pressure of calender bowls, particularly with schreiner calenders, and occasionally a rough spot or a fragment of metal or other hard material which has become embedded in a soft bowl will cause a regular succession of cuts or weak places over hundreds of yards of cloth.

Many faulty pieces result from the use of unsuitable finishing materials, sometimes owing to faults in the filling and sometimes owing to the finishing producing the wrong handle. Of such faults I propose to show several examples which illustrate the effects of applying unsuitable filling materials.

Salt finishes provide many examples of faulty fabrics. In some cases tendering of the cotton is caused by Epsom and Glauber's salts by the mechanical action of the salts changing their physical condition under the influence of heat and varying atmospheric conditions. This is particularly the case when traces of magnesium chloride are present in the salts. The rupturing of the cotton is then similar in nature to a peculiar effect which was produced in a certain wall in a finishing works. In this building the residual salts liquors from finishing were turned on to the floor to run to the drains. They came into contact with the wall and travelled, by capillary attraction, for some feet through the bricks. During the day, whilst steam was on and the place was warm, the salts remained in solution, but during the cooler night they crystallised. The ultimate effect was the disintegration of the bricks to a height of several feet, and the bricks could be crumbled with the fingers.

Apart from the damage actually caused in finishing processes one must consider some of the many varieties of faults produced by subsequent mishandling of finished cloths. A good example is a pattern of black cloth which is marked in places by a very distinct moiré effect. It was found that this piece was so marked by the effect of excessive pressure in a hydraulic press when the packing was done. Other common examples are the local fading of coloured goods when

partly exposed to light or to an atmosphere charged with chemical vapours. A common example of such an effect is the pink discolouration which is caused by aniline vapour coming into contact with bleached cloth which is faintly acid. Other troubles arise from making up, laundering, wrong storage conditions, and so on. Space will not permit me to deal with these points, but a number of the patterns produced will be self-descriptive.

Certain special sections of this discussion of cloth faults require a chapter to themselves, and I propose to mention a few points in connection with several sections.

Many cloths are dyed with "wood shades" for the rubber-proofed garment trade. They are resistant to the curing processes and of satisfactory fastness to ordinary conditions. A serious fault which often develops during wear is a reddish staining which occurs at those parts which are most exposed to rain. This is due to the slightly alkaline reaction of magnesia which is used in the proofing. The remedy appears to be to give the cloth a very thorough treatment with bichromate during the dyeing process.

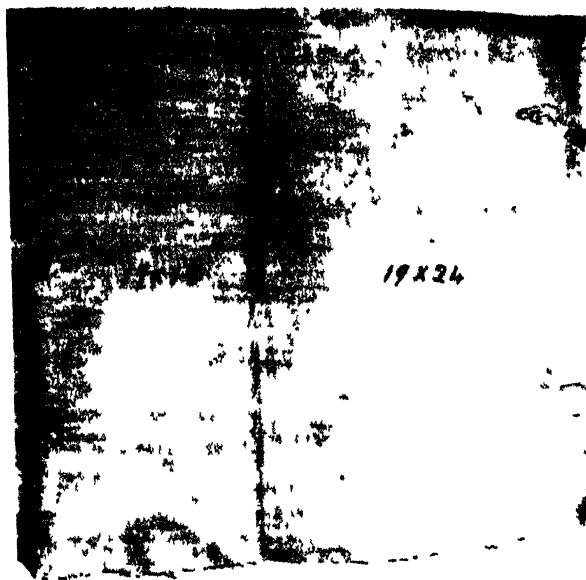
A discolouration of similar appearance to the last provided a problem of a different nature. In this case the brown direct dyestuff on a coat had turned a redder shade in the vicinity of the buttons. After some time it was found that the buttons were made synthetically and that formaldehyde was used in the process. Traces of formaldehyde left in the buttons were sufficient to change the colour of the cloth.

Decomposition of rubber proofings is often met, and it may be ascribed to the action of excessive fatty matter in the cloth, or to the action of traces of metallic compounds such as salts of copper and manganese, which exert a catalytic action and accelerate decomposition of the proofing, or to wrong mixing and curing. A certain danger limit for the copper content of cloth for proofing, that is, a limit of 0.01% of copper, is generally accepted and demanded in the trade. It is difficult, however, to reconcile such a limit with certain examples, for instance, a number of patterns which I possess contain over 0.04% of copper, and the proofing on these cloths showed no signs of decomposition after several years.

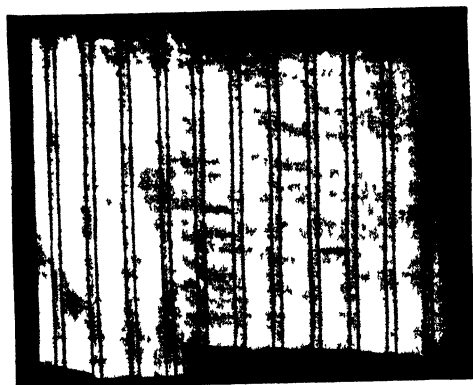
A familiar fault in rubbered fabrics is tendering caused by traces of acid left from the cold curing process. This is generally the result of inefficient "sweetening" with ammonia after the curing. The cold curing process is often the cause of curious effects of discoloration of the dyed cloths, as some of my examples will show.

With regard to rayon fabrics, several books could be written. I may cut short the discussion by pointing out that many of the faults which are found in rayon fabrics are similar to those described for cotton, except that they generally show more distinctly. For instance, weaving faults due to wrong reeds, rubbed and fractured threads, bars from wrong picking, and so on, have similar effects in both cases. Bright threads are produced by overstretching warps, by faulty shuttle-tensioning, and by faulty winding, amongst other causes. The mixing of different dyed yarns, of yarns of different counts, and of different dyeing affinities or lustre are all common faults which produce bars in the finished materials. It is not a rare occurrence to find yarns with different numbers of filaments mixed together in the same cloth, as in the patterns shown. The rayon maker, by inability to control the regularity of his materials, the winder, warper, sizer, and weaver all add to the number of faults found in most pieces, and it is not always easy to determine who is responsible for many of the faults.

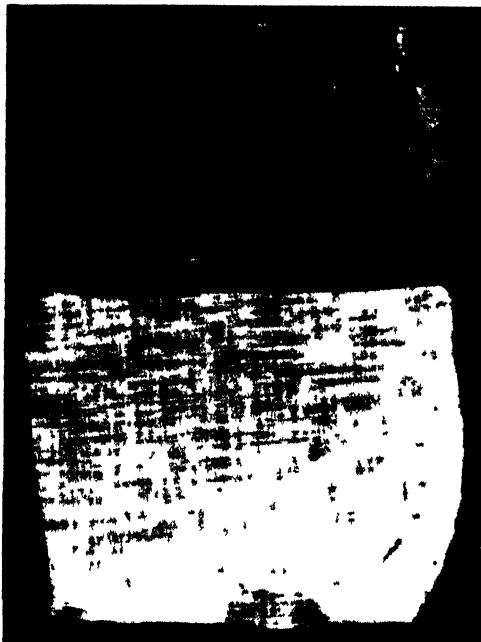
In spite of the excellent machines and workmanship, and the careful control exercised in the rayon manufacture, the threads often vary in their lustre and capacity for dye-absorption. This is partly a matter of chemical condition and partly due to the physical condition of the filaments, which may be seriously affected by minor differences in circumstances. The variable dyeing affinity of



Defect due to change in yarn counts



Defect due to slackness in coloured warp
yarns causing snarls or loops during weaving



Defect due to zinc chloride—heat tendering
Upper illustration shows effect due to use of
hot iron



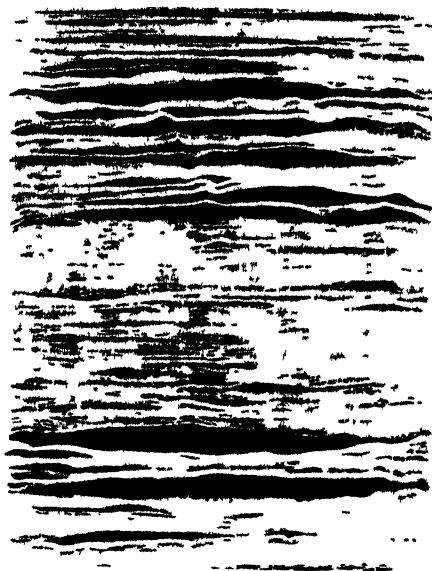
Mildew effect on dyed border when over damp, exhibiting
change in dyestuff



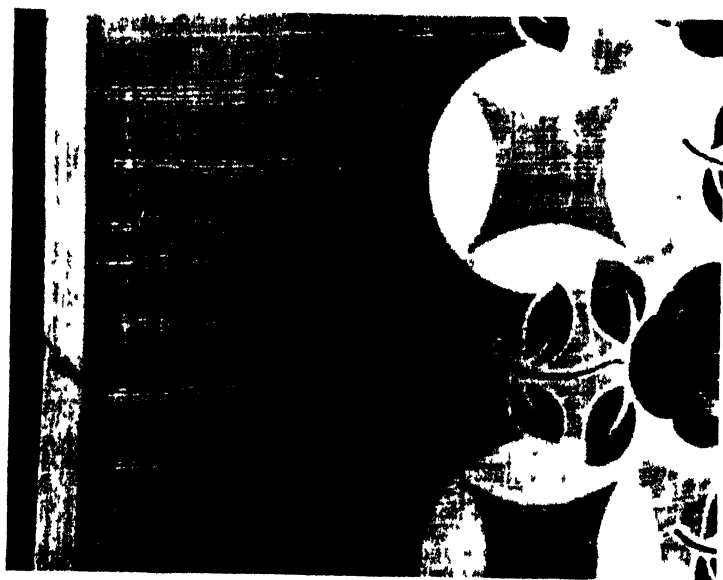
Lead staining



Lime staining



Defect due to employment of different qualities of viscose with certain sections being destroyed in bleaching



Resistance to dyeing due to wax from pins spread by steaming

The Author wishes to express his indebtedness to Mr. G. B. Slater for the negatives and photographs from which these illustrations are prepared

viscose threads presents a serious problem, which is being solved partly by control and research in the rayon mills and partly by the use of certain colouring matters which possess unusually good levelling properties on variable yarns. Weft bars from variable-dyeing yarn are very common, and their effect is emphasised by the use of single and mixed colouring matters of unsuitable types. The patterns will illustrate a number of faults arising from these causes.

Rayon fabrics are liable to most of the accidental stains and faults which are found on cotton, as my examples show. In addition, their relatively low strength when wet and under certain other conditions leads to more frequent mechanical damage. There are often marked chemical differences which give different resistance to chemical attack. Sometimes two such different yarns will be mixed in one cloth with the result, as some of the patterns show, that part of the cloth will become tendered and part remain strong.

Acetate silk is liable to hydrolysis by alkalis, soap, and even by water, with a consequent change of its lustre and dyeing properties. Fortunately, research in all parts of the industry is enabling us to produce filaments of greater strength and uniformity of properties, so that a number of the now common faults may be lessened.

I would like to make a few remarks about crêpe fabrics, which are favoured with constantly increasing popularity in all classes of fibres. They present many difficulties in their production, and these difficulties lead to numerous faults whose sources are almost equally difficult to trace. By the modern processes crêpes are made from highly-twisted yarns which are difficult to handle, and this raises many problems in dyeing and finishing. Slight variations in the turns-per-inch of the threads, thickness, tension, etc., make very great differences in the finished cloth, and cause visible distortion of the surface of the cloth. In addition carelessness in shrinking or in handling the cloths during dyeing and finishing has been the cause of many faults. These are often invisible, without careful search, in the grey state, but become grave faults when finished. A number of examples of faults in crêpes are shown in my collection of patterns, but details of many cannot be given here. There are so many ways of going wrong in the production of this type of fabric that it will be a magnificent achievement for those who first succeed in making a perfect crêpe cloth.

One difficulty in weaving is due to the liveliness of the crêpe yarns, which tend to twist into snarls owing to irregular drawing-off from the pirns and for other reasons. In order to reduce this tendency it is a fairly common practice to steam the cops. This sometimes leads to unevenly-steamed yarns being put into the same cloth and, therefore, to bars of irregular crêping in the finished cloth. An example of another danger which may arise from this practice is one in which certain voiles were involved. Some of the weft yarn was steamed and woven and some was not steamed. The cloth was afterwards printed. Certain portions of the fabric remained undyed, so that the print had a speckled appearance. Unfortunately, the paper tubes on which the weft had been wound had been impregnated with paraffin wax. The steaming had spread this on to short lengths of the yarn, which had thereafter resisted the dyeing. There were several other interesting points in connection with this cloth, but they would take too long to describe.

I set out to traverse a very wide field, involving many stages where faults might arise to affect finished fabrics, and I have described, in brief, as many examples as space would permit. In doing so I have been forced to omit many interesting and important details and examples, and to produce a catalogue-like text. So that the treatment of the subject should not lack interest and value, all the examples quoted will be illustrated by patterns numbered as in the text and labelled with the particulars of the case. In addition there will be produced a number which are not described here, but which will be self-explanatory. These will be available for examination and discussion during the conference.

DISCUSSION

The Chairman expressed interest in the fabrics which exhibited light specks after dyeing, these specks being dead cotton. The detriment of dead cotton or neps was not merely confined to their effect on dyed goods. He had had an instance of a bleaching cloth, undyed, which was finished and sent to a surgical plaster manufacturer. Complaints from users in various hospitals found their way back that the fabric came away from the adhesive substance. The use of a superior cotton remedied this defect.

Dr. Bean said there still appeared to be much ignorance on the subject of dead cotton.

Mr. J. Lomax, referring to the example of fancy goods with coloured weft, showing bars attributed to the use of different pirns, said that he had had similar cases in which it had been difficult to assign the real cause. The question to answer was whether the mixing was in the spinning or in the dyeing. Mr. Lomax also referred to some cotton stockings which he had recently examined and which exhibited stripes, said to be due to mercerising. But these goods had not been mercerised. The defect was due to dirty yarn.

Replying to Mr. Lomax, Dr. Bean said that of the first defect he had come across many examples. It was not always possible to assign the blame exactly. He did not think it difficult to identify defects due to dirt or oil, as these were suspected and spotted. He agreed with Mr. Lomax, who had pointed out that deceptive appearances existed for which blame could easily be wrongly assigned.

The Chairman said he had encountered cloths of the same reed and pick showing defects put down to mixed cotton. He would like Dr. Bean's views as to how far yarn and fibre differences accounted for these defects. In the case of some discoloured cops he had been informed by the manufacturer that these were due to the yarn having stood in the mule overnight. The length of yarn from the spindle to the draw rail was at fault, having been "fogged" when standing in the mule.

Dr. Bean said that though cases of yarn "fogging" were known, the differences of shade to which he had referred were certainly not due to this cause. They were attributable to the use of different yarns, yarns composed of different growths of cotton varying in staple and colour. Such differences could clearly be seen in the grey cloth, though they disappeared on bleaching. After dyeing, the differences showed up as bars. He had known cases of yarns in the loom becoming "fogged" so that the woven cloth was dirty for several feet.

Mr. W. Kershaw suggested that the defect was perhaps more prevalent in two-fold poplins and that it was extremely difficult to remove.

Mr. C. M. Whittaker said he thought that drying conditions might perhaps be to some extent responsible for the trouble. There were days at Droylsden when it was impossible to dry yarns in air-circulating stoves, since "fog" so circulated through yarns produced stains which were extremely difficult to remove. He thought that the fancy twister had not realised what effect on the dyeing of his yarn different steam-box conditions had.

Mr. W. W. L. Lishman asked whether conditioning of yarns at different periods had an effect on the yarn. Water might vary as between morning and night. Fermentation might be engendered, and other changes might arise which would modify the reaction of the yarn to dyeing. A considerable interval of time, such as between spinning and weaving, might aggravate or even give rise to differences in the yarn when dyed and finished.

Dr. Bean, in reply, agreed that such changes might occur and might be responsible to some extent for the troubles under consideration, but he had never been able to put his finger on a specific case. He thought experiments could be made to attack this problem. But in his case he was often only supplied with a few cops from which it would appear impossible to trace conditioning periods

Mr. F. Kendall referred to the vogue for crêpes. These fabrics were causing more trouble than any other type of material. He attributed many of the faults in crêpes to the lack of craftsmanship now available. Payment for quality in production would materially reduce the faults. He wished to know if Dr. Bean could put forward a theory to account for differences in crêping power.

To the point raised by Mr. Kendall, Dr. Bean said that the perfect crêpe was yet to be woven. Fabrics, in his experience, which were alike in weave, yarn counts, filaments and twist, and which had been very carefully manufactured and finished yet exhibited flat crêpe, half crêpe, and full crêpe. He could find no explanation of this. Of course it was possible sometimes to discover very real differences, such as a variation of twist of as much as 25 turns per inch, but it had been proved that this alone was not the cause of the trouble.

Mr. Kershaw suggested that one line of attack on the problem of defects would be for all concerned to exchange information thereon. By proper co-operation a statistical review might be prepared.

London Section

ANNUAL MEETING

The eleventh annual meeting of the London Section of the Institute was held at 104/105 Newgate Street, London, on Monday, 29th May 1933. At the outset, Mr. Frank Henley presided and there was a fairly representative attendance, including Messrs. A. E. Garrett, J. Howard, and E. Wigglesworth (Vice-Chairmen), Mr. Arthur R. Down (Hon. Secretary), Mr. Albert Gowie (Assistant Hon. Secretary), and Mr. J. D. Athey (General Secretary).

The annual report of the Committee showed that whereas 26 members had been lost owing to resignation or transference, 19 has been added, making a total of 129 at 1st January 1933. Five public lectures had been held last session, two of which were delivered in the Clothworkers' Hall, by kind permission of the Worshipful Company of Clothworkers, and three in the hall of the L.C.C. Trade School, Barrett Street. The Committee recorded its appreciation and thanks for the facilities in question. Three informal discussions had taken place in the Members' Room. The Committee regretted a falling off in attendance at meetings and appealed to members for support in this connection. It was pleasing to note that the Section had dealt with a considerably larger number of inquiries during the year and the expansion of facilities at Headquarters had proved highly advantageous. It was proposed to arrange for a special visit to mills in Lancashire during the present year, and it was hoped that sufficient support would be forthcoming to enable completion of arrangements. A Standing Advisory Committee on Education for textile distributors in the London area had been formed and had received requests for the framing of suitable courses. The Committee is associated with various educational bodies and among those upon which members serve may be mentioned the Central Advisory Committee of the London County Council, the London County Council Barrett Street Trade School Consultative Committee and the City and Guilds of London Institutes. Finally, the Committee recorded their high appreciation of the services of the Chairman, the Hon. Secretary and Assistant Secretary, and members of the staff of the Drapers' Chamber of Trade.

The report was adopted.

Mr. J. Howard was unanimously elected Chairman of Committee for the ensuing year, whilst the retiring Chairman was most warmly thanked for his excellent services over the past three years.

Mr. Howard then took the chair and said it would be his especial endeavour to promote increased membership.

Messrs. A. E. Garrett, P. J. Neate, E. Wigglesworth, and F. Henley were elected Vice-Chairmen.

Mr. Down reported 20 nominations for election to Committee, and the members nominated were recommended to Council for election, as follows—Messrs. A. B. Ball, G. M. Canham, C. H. Colton, A. R. Down, A. E. Garrett, A. Gowie, F. Henley, H. B. Heylin, J. Howard, C. W. James, A. Mason, W. H. Matthews, R. S. Meredith, L. J. Mills, P. J. Neate, T. C. Petrie, G. A. Rushton, C. F. Sunderland, W. C. Whittaker, and E. Wigglesworth.

Mr. A. R. Down (Hon. Secretary) and Mr. Gowie (Assistant) were re-elected and gratitude was expressed by the Chairman for the continuance of the secretarial service.

A Sub-committee (Messrs. Petrie, Garrett, Henley, Wigglesworth and the Secretaries) was appointed to consider propaganda for increased membership.

Yorkshire Section ANNUAL MEETING

Meeting at Midland Hotel, Bradford, 22nd June 1933. Mr. J. Dunville presided at the outset and there was a representative gathering of members.

The minutes of the previous annual meeting were approved.

The Chairman welcomed the members present, reviewed the activities of the Section during his term of office, and warmly thanked all who had assisted. It was satisfactory to note that the Section was well represented in the Fellowships and Associateships awarded during the year.

(1) *Committee*—The Chairman announced that 11 nominations were received for the 10 seats on the Committee. To avoid an election, however, Mr. Kendall withdrew his nomination. Therefore the following members were elected subject to approval by Council—J. Dumville, A. Frobisher, N. H. Chamberlain, E. E. Cockcroft, J. R. Healey, W. Morley, H. Richardson, T. H. Robinson, A. Saville, and H. Turner.

It was agreed that if any vacancy on the Committee arose during the year, the name of Mr. Kendall should be added.

(2) *Officers*—Moved by Prof. Midgley, seconded by Mr. R. G. Bailey, Mr. T. H. Robinson was unanimously appointed Chairman.

Mr. A. Bailey was appointed to the position of Vice-Chairman.

Mr. Dumville said that with regard to the Secretaryship, the Institute desired a revision to past practice, and it was hoped to secure the services of an Honorary Secretary—a member in close touch with textile affairs. Mr. Broxholme had been most courteous and helpful and the change now suggested was entirely related to policy.

Mr. Binns, in proposing that Mr. Walter Garner be appointed, said he believed there were at least two others prepared to help in any possible way.

Mr. Dumville seconded, Mr. Saville supported, and the motion was heartily carried.

Mr. Garner accepted and suggested an assistant.

It was agreed to appoint an Assistant Hon. Secretary, and Mr. H. S. Newsome was appointed.

(3) *Section Meetings for next Session*—Discussion followed regarding Papers or Lectures for the ensuing Session. A number of suggestions were approved and referred to the Emergency Sub-committee to be considered and dealt with.

It was recommended that three meetings in relation to the Institute Diploma Scheme, similar to the meetings held previously at Bradford and Halifax, be arranged—at Huddersfield, Keighley, and Leeds. In the case of Leeds, a joint meeting with the Cartwright Club was suggested.

It was agreed desirable to promote one general meeting at Bradford—either a Luncheon Meeting or a meeting at the Town Hall.

Prof. Midgley urged the importance of securing papers of scientific or technological interest and suggested "The Sulphur Content of Wool" as a subject, and an invitation to Mr. A. T. King.

Mr. Garner suggested a discussion on colour fastness, with two or three contributors.

The General Secretary was asked to make inquiries about a visit to the forthcoming Machinery Exhibition at Bradford.

NOTES AND NOTICES

Institute Membership Subscriptions

Whilst the Finance Committee of the Institute is grateful enough for the excellent response to the recent issue of an appeal in respect of unpaid membership subscriptions, yet the outstanding amounts in this connection are considerable. In these difficult times, the policy of the Committee is not one of rigid adherence to the prescribed conditions, and tolerance may be exercised in exceptional circumstances. The unfortunate aspect of deferred payment, however, is that of the additional cost of collection which the issue of frequent appeals imposes. The Committee, therefore, would greatly esteem due consideration of this matter by those Members to whom such appeal has to be made. The maintenance of a satisfactory rate of influx of new Members continues, as the record of elections at each meeting of Council plainly indicates. A limited number of our Members have performed excellent service of late by introduction of new Members and it seems obvious that in this direction many more could assist materially. The Secretary of the Institute would be glad to follow up recommendations by Members as to names of persons regarded as suitable for approach regarding membership.

Cotton Trade Mission to India

Although this Institute is not connected in any way with the movement, yet it is interesting to note that our President, Sir William Clare Lees, has been selected as the head of the delegation representing the British cotton industry which is to proceed to India early in September to lay before the Government representations on the subject of Indo-Japanese commercial relations. It is understood that, in the first instance, the delegation will meet representatives of the Bombay Millowners' Association and probably those of many other organisations interested. It is certain that our President will have the good wishes of our Members generally for the success of this most important mission, and Sir William's previous experience in delegation enterprises should assist him greatly in his endeavours. The delegation will consist of Sir William Clare Lees (Chairman), Mr. S. S. Hammersley, M.P. (Federation of Master Cotton Spinners' Associations), Mr. R. Houghton, J.P., and Mr. F. Longworth (Cotton Spinners' and Manufacturers' Association), Mr. Angus D. Campbell and Mr. E. Raymond Streat (Manchester Chamber of Commerce).

Leeds University—Professorship of Textiles

Mr. A. T. King, B.Sc.(Lond.), F.I.C., has been appointed by the Council of the University of Leeds, to succeed Professor A. F. Barker, in the Chair of Textile Industries. His appointment takes effect at the beginning of October next. From 1907-1911 Mr. King was Demonstrator and Junior Lecturer in Chemistry at Leeds University, and for the ten succeeding years held appointments on the academic staff of the Imperial College of Science and Technology, London University. In 1921, Mr. King was appointed Chief Chemist to the Wool Industries Research Association, Torridon, Headingley, Leeds, and undertook the organisation and development of the chemical side of the Association's work. He has published many reports and papers in scientific and technical journals, including the *Journal* of this Institute.

The Institute Foundation Fund

Reduced yield of annual interest from the Institute's Foundation Fund investments has recently received the consideration of both the Finance Committee and the Council. The diminished income affects most important branches of the Institute activities—publications, the competitions scheme, and scholarship awards. In regard to the competitions, since the scheme was originally launched as a result of the availability of the Crompton Memorial Fund, the prospectus of competitions has been considerably expanded during a time when income has been diminishing. It was felt at the time of the inauguration of the scheme that the fund provided by Mr. John Crompton might be considerably augmented by gifts of a similar character, but any hopes entertained in this connection have not been realised, though the Competitions Committee have been grateful for support from Messrs. R. Greg & Co. in regard to the competition for fancy yarns. The Committee desire the fact to be known that they would appreciate even small contributions towards the prize-money involved. The competitions scheme is now well established and it is hoped that any curtailment of the programme may be avoided.

REVIEWS

Furs and the Fur Trade. By J. C. Sachs. Published by Sir Isaac Pitman & Sons Ltd. (London). Third Edition (137 pp. and index, price 3s.).

To be the author of a successful work is no mean feat; to be the author of a work dealing with furs and the fur trade requires something more than penmanship or imagination, and the fact that this book has now reached its third edition, speaks highly of the capabilities of one who is recognised in the fur industry as an expert and experienced "Fur-man."

In reviewing the book, one must not lose sight of the fact that it has been expressly written for the enlightenment of the layman, and his wife. To use the author's own words, "it is strictly non-technical," and because of this, its appeal to furriers must necessarily be limited to those who enjoy reading works of a general nature. The fur industry of to-day is so highly specialised, that the demand for technical information far exceeds the number of such books. But, for the layman, it is an extremely useful guide and introduction, from the romance to the reality of a trade, as old as Adam, which bears a name not always as sweet smelling as one might desire.

There are particulars of many fur bearers, as well as sound advice to those thinking of entering this profession, beset with so many difficulties. Some of these difficulties are enumerated in the chapter dealings with Markets and Marketing, noteworthy for its story of the frantic speculations both in New York and Canada, when the supremacy of London, as the chief fur market of the world was severely tested, until in 1920, the fur auctions at St. Louis were abandoned, and the London Sales were held as usual. The resulting crash brought many firms to their knees, but the casualty list in Britain was indeed small when compared with the wholesale slaughter of the would-be "get-rich-quick" of the U.S.A. The description of the auction sales themselves is very complete, even to the mysterious methods adopted by the various bidders, and the author's notes on the art of bidding successfully might well be used with advantage in other markets.

The preparation of the skins for manufacture is dealt with strictly for the layman, and gives a good idea of the most important processes through which the raw pelts must pass, before being in a fit state for manufacture into garments.

As to the actual manufacturing of furs, Mr. Sachs describes the art as such a highly technical one that to describe it shortly would be quite impossible, and that the feats done with the fur knife must be seen to be believed. As a practical fur-man, the chapters of most interest to me were those dealing with the history of the trade, and the list of the wear or durability of a number of fur bearers. It would perhaps have been of greater interest and value if Mr. Sachs had explained the difference in durability which skins processed undergo, such as the better wearing quality of the unplucked beaver over one which has been unhaird.

Another point which the author overlooked, and one which I cannot remember having seen stated elsewhere, is that, as a general rule, the durability of fur

bearers living in or near water, is far greater than those confined strictly to the land. Equally important is the fact that when these water or guard hairs have been removed, the durability is lessened. "Furs and the Fur Trade" is, however, extremely interesting and good reading to all those who may be interested in the animals or the trade, and at the moderate price of 3s., should certainly be included in your library. E. A. A.

Zwirne; ihre Herstellung und Veredelung. By Heinrich Bruggemann. Published by R. Oldenbourg, Berlin, 1933. (461 pp. and 29 tables, G.M. 40.—).

This is a series of lectures delivered at the Technical High School, Munich, expanded to form a text book not only for the use of the student but also for those engaged in the industry. The author has produced a work which represents an intensive study of the production of doubled yarns and threads of many types. The book is not simply a description of the various types of machines and their methods of use garnished with illustrations from trade catalogues, but a closely detailed account of the best methods and processes used in the industry whereby it is shown how these may be handled in order successfully to obtain the desired results. To achieve this the author has not only considered the normal machinery at present in use but also the suggestions of many inventors and authoritative writers on the subject in the technical press, and a large bibliography of nine pages provides ample material for the reader who wishes to pursue his studies in the subject.

The description of the many different kinds of doubled yarns and the step-by-step methods of producing them are considerably simplified by the inclusion of a large number of drawings, of which there are 364, arranged in 29 tables collected together at the end of the book with a separate index. The work also includes many algebraical formulæ, e.g. calculating the design, production, and cost with practical worked-out examples shown; their method of application.

Detailed descriptions of the processes for improving the yarns such as gassing, washing, bleaching, dyeing, pressing, mercerising, polishing, impregnating, etc. are all considered, and to assist the reader to a more complete grasp of the chemical side of these processes an excellent glossary (37 pages) is included. The book is well produced and should be included in every technical library as a standard text-book and work of reference on this specialised branch of the textile industry. H. F.

The Methods of Cellulose Chemistry. 482 pp., Appendix and Indexes. By Charles Dorée. Published by Chapman and Hall Ltd., London, 1933 (21s. net).

The enormous strides made during recent years in the scientific and industrial development of cellulose chemistry have brought in their train an increasing demand for new and reliable methods of standardisation and analysis, both with respect to cotton and its derivatives on the one hand, and to wood, wood pulp and derivatives on the other. According to the author the purpose of the present volume is "to give full working details of a selection of the best methods . . . and to illustrate the use and application of the methods by full abstracts of original investigations . . ." The book embraces three parts dealing respectively with (1) normal cellulose, (2) synthetic derivatives of cellulose, and (3) investigation of the compound celluloses.

The first part of the book relates to "normal cellulose" and includes such topics as preparation of standard cellulose; measurements of viscosity; copper number; alpha cellulose; acidity; tensile strength of hair, yarn, fabric, etc. as well as a separate chapter devoted to such subjects as oxycellulose; hydro-celluloses; degradation products of cellulose and investigations concerned with "cases of damage in cotton and linen cellulose." Due to the fact that much greater clarity now exists in regard to the structure of cellulose, it has been possible, thank essentially to the important researches carried out in recent years at the Shirley Institute on behalf of the British Cotton Industry Research Association, to formulate new qualitative and quantitative methods analysis for cotton and other cellulose products based on sound experimental research, so that these methods are rapidly coming into general adoption. Examples of such are viscosity and copper number determinations; Methylene Blue absorption value, etc. The author has given a very good up-to-date review and criticism of the best methods of cotton analysis based principally on the work of the Shirley Institute. The properties of dispersed cellulose, oxy- and hydrocellulose with methods of isolation and analysis of same are also covered quite fully. The formula for soda

cellulose ($C_6H_{10}O_5$)_nNaOH given by the author (pp. 91, 92) is not in agreement with later work (*J. Amer. Chem. Soc.*, 52, 3257, 1930), indicating this as $C_6H_{10}O_5 \cdot NaOH$ —a view supported by the quoted observations of Neale. In view of the generally admitted inhomogeneity of all oxidised celluloses, it seems advisable to abandon the term "oxy-cellulose" and to use instead the name "oxidised cellulose."

In Part II the reader is introduced to cellulose derivatives such as the nitrate, xanthate, acetate, other esters and ethers, the mode of preparation and analysis of which are also given.

The last part of the book (Part III) deals with the "Investigation of the Compound Celluloses" and the careful work of American authors has been drawn upon quite largely. Due to the fact that the structure of lignin and of other constituents of wood fibres is still unknown, the methods of wood and compound cellulose analysis are still largely empirical, and in consequence far from satisfactory—a remark which applies with equal force to the determination of lignin, cellulose and hemicellulose in wood fibres. A careful, critical review is given of the best known methods, including an interesting chapter on a "General examination of plant tissues."

The final chapters deal with the chemistry of isolated lignin and of pectic substances. In the former, a review is given of the author's and other researches, but in the present uncertain state of the subject it is not possible to draw any definite conclusions regarding the structure of lignin.

The author is to be congratulated on the sound and careful literature review provided prior to the discussion of each analytical procedure, although the reviewer has a decided personal preference for the separation of all theoretical discussion from the actual analytical details. It is admitted, however, that this would probably involve a division of the work into two distinct parts.

The book is well printed and is remarkably free from typographical errors. On p. 6 "steel" is spelled "teel"; on p. 7, title in table, column 2, reads "solubility in" instead of "solubility of." The use of the word "after" in such expressions as "after Clibbens and Geake," etc. should be changed in any future edition to "according to," the latter representing the correct translation of the German word "nach" when used in this connection. It would also add to the value of the book if all concentrations were given in percentage weights rather than as densities, Twaddell degrees, etc.

The book represents a valuable contribution to the subject of cellulose and wood chemistry, providing as it does a careful and critical review of synthetic methods and the best analytical procedures and can be strongly recommended to both scientific and technical worker.

Certainly if the author's advice that "the student should on no account omit to read the original papers connected with any method he may be using" be conscientiously carried out, especially in the case of the numerous Shirley Institute researches already referred to, it may be stated with confidence that the reader will acquire in this manner a liberal education in the aims, art, and technique of cellulose research.

H. H.

PUBLICATIONS RECEIVED AND ADDED TO THE INSTITUTE LIBRARY

Das Rechnungswesen in der Textilindustrie. By Von Diplomkaufmann Dr. Heinrich Herches. Published by Oesterreichischer Wirtschaftsverlag, Wien, Austria. (112 pp. and Bibliography. Price RM. 9.)

Covers the German system of costing throughout the wool manufacturing industries. Would have been of greater value had references been given to costing work in other countries.

Department of Scientific and Industrial Research. Water Pollution Research Board. Technical Paper No. 3. Price 7s. 6d. net.

This booklet is entitled "The Purification of Waste Waters from Sugar Beet Factories." Its authors are E. H. Richards and D. W. Cutter. It records investigations on a semi-commercial scale on the method of biological filtration of the waste waters from sugar beet factories.

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THE PERFORMANCE OF TWO NEW FINISHING MACHINES ON LINEN

By E. BUTTERWORTH

Chairman Mr. J. W. McMYN

INTRODUCTION

Finishing machinery has become very much standardised during the past few decades, modifications have been made with a view to increased speeds or greater regularity, but the chief methods are well established.

The main object of the following notes is the description of two machines which have been developed during the past few years and which present certain novel features.

One of the great difficulties at present in work on finishing, especially when closely related to practical conditions, is the impossibility of determining directly the stresses, etc., actually operating, which prevents any attempt at adequate control. It is not claimed that any such advance has been made and the work rather suggests problems than solves them.

The alternative method of attack on the problems involved is the determination of the physical characteristics of the fabric at all stages. Several relatively simple methods have been evolved or adapted to be suitable for the conditions of a works laboratory. The problem is simplified, in the case of linen, by the fact that the type of fabric is limited, for example in the case of thickness, a dial micrometer capable of reading to 10^{-3} mm. is adequate. Such methods are suitable for the analysis of a problem but the machines are necessarily built up on a trial and error basis and the final "appeal" of a finish is still largely a matter of chance and the finisher's skill.

A Three-bowl "V" Type Friction Calendar for Refinishing Single Cloths

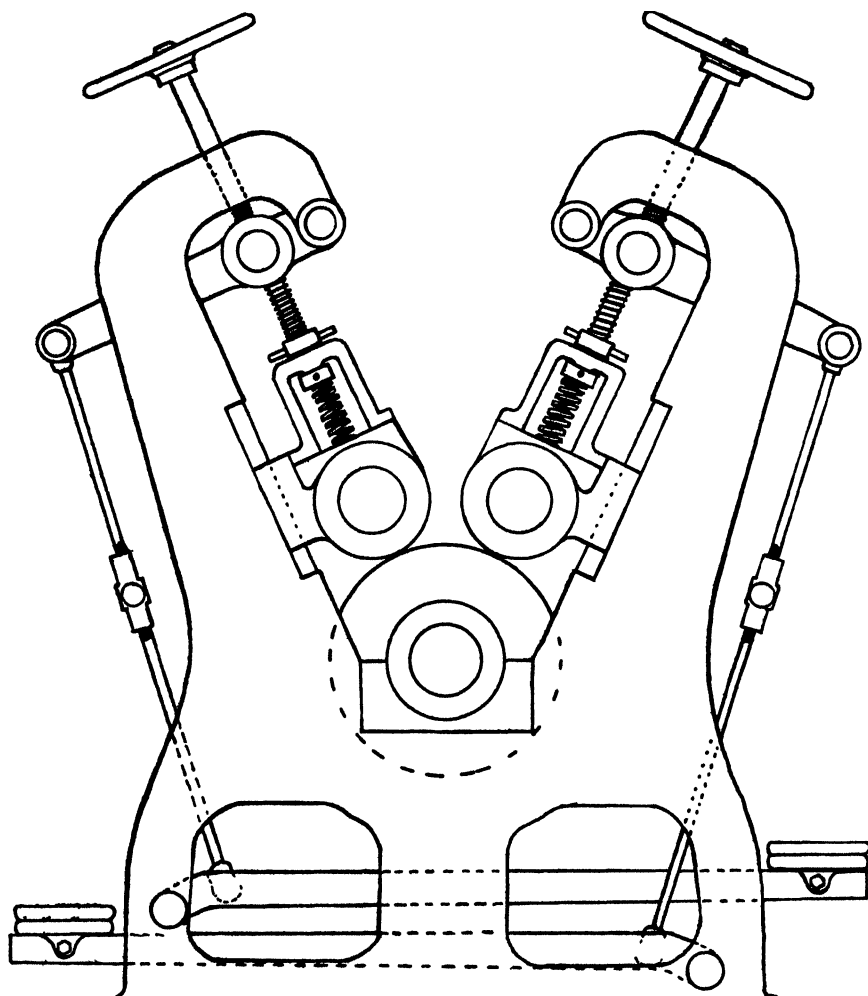
The lustre and handle of a fabric are its most important and striking properties in selling and later in use. Any finish or treatment which tends to enhance the full natural lustre of linen will be readily appreciated, and especially one which would maintain this appearance after laundering. The laundry finish, whether applied making up or in actual use, lacks many of the distinctive features stressed by the finisher and it was with a view to overcome this weakness that the new machine¹ was developed (Fig. 1).

The usual type of finishing calendar is unsuitable for dealing with short lengths of cloth both as regards creases, unevenness, and method of feeding, whereas the Decoudun, while designed to take short cloths as in laundry work, does not produce a smooth enough, or lustrous enough, finish when compared with the original finished piece.

* This issue completes the Papers read at the Conference.

The machine developed comprises a large cotton bowl (24 in. diameter), on which rest two steel bowls (12 in. diameter) placed as near together as driving conditions permit.

Two nips are thus formed, one behind the other on the same bowl. The first nip holds the cloth so that the second nip can be arranged to give friction, if necessary. The pressure, which need not be so great as in the finishing calender is applied by compound lever through springs. One feature is that the pressure may be reduced to zero and relatively small pressure applied by "lifting" the weight of the bowls (unscrewing the springs). Considerable variety of conditions may thus be attained.



Patent V type Calender

FIG. 1—Method of applying pressure shown in detail, bearings etc. skeleton, driving arrangement omitted.

One use of the machine is refinishing cloths after hemming, making up or laundering, where it takes the place of the Decoudun finishing calenders in the ordinary routine. The comparatively high finish imparted to damask after laundering suggested the use of this finish for general laundry use and the following

results were obtained in testing the effect of repeated treatments. Preliminary tests on identical qualities at thirty or more public laundries showed clearly that the ordinary Decoudun finish did not vary greatly and was much inferior to the original or to the refinished fabric.

It was necessary to examine whether this finish could be maintained after repeated launderings. A trial was therefore made in which cloths cut from the same piece were laundered twenty-five times, the control sample being laundry finished on a Decoudun calender while the test sample was finished on the new machine.

The following table summarises these results—

Laundering Trials (25 washes)						
Sample		Lustre Number (G)			Tensile Strength	
		Along Warp	Across Warp		Warp	Weft
Control finished	... ..	2.85	2.09	...	175.2	163.2
Ordinary laundry finish	...	0.78	0.62	...	93.0	73.7
Special calender finish	...	1.69	1.47	...	109.5	90.8

The laundering was carried out in all cases in the same machine with ordinary soiled goods. The lustre number was obtained by means of the Goerz glarimeter and the tensile strength estimation was carried out on a Goodbrand machine using 2 in. strips conditioned at 79% R.H. and 70% F.

Further, to test whether the calender has any more drastic action on the cloth than the Decoudun, a trial was made by submitting test pieces (different quality from the laundering trial) to one hundred finishing treatments.

The fabric was damped between each treatment and allowed to condition overnight or longer. Each "finish" entailed two runs through the calender reversing (on the second run) and occasionally a third if damping had been too heavy. A similar trial was carried out on the laundry Decoudun.

Sample		Lustre Number			Tensile Strength	
		Along Warp	Across Warp		Warp	Weft
Control finished	... ..	1.85	1.60	...	246.2	282.7
100 Finishes—laundry	...	0.98	0.54	...	222.2	234.8
100 Finishes—calender	...	2.30	1.85	...	219.8	258.9

No chemical change (degradation) is shown by this treatment, the solubility number⁴ being unchanged, finished sample 4.8, laundry finish 5.1, calender finish 4.5.

In general the calender finish gives a higher breaking stress, which is marked in the case of the laundered samples. Tensile strength cannot alone be regarded as criterion of wearing quality but these results find support in some previous work⁴ where it has been shown that various samples of finished damask lost less weight in laundering than the same sample unfinished whether bleached or unbleached.

The explanation is, presumably, that the smooth surface of the fabric and close packing of the fibres in the finished sample resist abrasion in washing and normal use.

Further comparison has been made between the laundry method and the new method by laundering and finishing identical cloths of a range of seven qualities on the Decoudun and the calender.

The six samples exhibited have been laundered together five times, three have been finished in the normal way (two runs through a Decoudun calender) and the corresponding samples have been finished on the V type calender. The difference in lustre and handle is marked.

The only difference in handling the two sets was in drying, since the Decoudun is used on wet cloth (i.e., from hydro extractor) whereas a calender can only be used successfully on "conditioned" fabric.

This necessity for outside drying is a disadvantage in ordinary laundry routine since it would entail extra operations, "flat work" being usually ironed dry in the Decoudun.

It has been found that this difficulty can readily be met by drying on a suction Decoudun and finishing on a V type calender. One run is sufficient to bring the fabric to the required condition and the method is more convenient and more easily controlled than stove drying.

The speed of the machine (60 yards per minute) is considerably greater than the Decoudun so that the output can be maintained. One characteristic of the finish is shown in the case of goods containing dyed or printed effects where the dyed portions are more highly contrasted due to the smoother, more regular surface.

The results show that the new method compares favourably with the normal laundry finish as regards damage to the cellulose and tensile strength while the lustre and handle are markedly superior.



FIG 2—Houghton Beetle, showing lifting of beams *Photo "Belfast Newsletter"*

Note on Lustre Number

The figure given expresses the ratio between the intensity of reflected light and diffuse light for an arbitrarily chosen angle of incidence.

The drawbacks of such a method of evaluating lustre are self evident but the instrument is rapid and convenient in use since it does not entail the cutting of the cloth and it has been found of value in routine work.

The use of a ratio limits the scope of the instrument since neither actual intensities nor the form of the "lustre curve" is obtained, both of which have been shown to give considerable information in works finishing processes.

The ratio G is obtained in the following way.

The fabric is assumed to reflect light diffusely, that is, ~~equally~~ in all directions following the Lambert law, with intensity D , in addition at the reflecting angle an additional intensity R is obtained. The total intensity at the reflecting angle is thus $R+D$, and the ratio of the total intensities is

$$\frac{R+D}{D} \text{ which is written } G+1.$$

G is therefore R/D .

An All-metal Beetling Engine (Houghton Patent)

The high cost of beetling has led to numerous attempts to modify the existent wooden faller beetle, to accelerate the effect or to facilitate handling of the cloth, both objects being to reduce cost. The high maintenance cost of the wooden fallers prevents any simple modification of the old design from producing radical improvement and the machine under consideration⁵ is a distinct departure. A description of the mechanical features has already appeared³. Briefly the whole machine is constructed of metal* and maintenance of the beetle hammers has so far been negligible. The vertical wooden faller of the older engine is replaced by a cast steel double-ended hammer and the wooden wiper beam by two camshafts. Two beams of cloth, one on each side of a row of hammers, are beetled at once, the hammer falling by gravity one side, being lifted by the opposite cam just over the dead centre and falling on the opposite beam. The number of blows is limited, as in the old type beetle, by the fall of the hammer under gravity. Any attempt greatly to increase this rate (about sixty complete cycles per minute) results in a marked increase in power consumed which is undesirable and unnecessary. Moreover, too high a speed limits the beetling action (Fig. 2).

The hammer is pivoted, and the camshafts lie, below the cloth beams so that these may be lifted clear of the machine. This minimises risk of stains but its main object is to allow the filling and stripping of the cloth outside the machine, so accelerating the production.

At the completion of a "round" the beams are lifted from the engine and dropped into a stripping frame. New beams are substituted immediately so that the process is almost continuous, the time occupied in changing being about ten minutes.

From the time saved due to facility of handling considerable decrease in cost is possible but the capacity of the machine in reduction of costs is most evident in the time required for beetling.

Under the old method the time taken in beetling varied (with quality and finish required) from 12 to 40 hours actual beetling on the beam, with the new machine this has been reduced to a maximum time of six hours, with corresponding increase in production.

It is not self evident that the operation could be shortened to such an extent but an analysis of the process showed the possibility and this was confirmed by trial on an experimental machine.

As in many finishing machines the exact calculation of the physical action on the cloth is difficult and uncertain owing to the lack of data determining the operating forces under the conditions prevailing.

* A wooden model was used to show the essential features.

The weights and speeds of the hammers were found by experiment and the precise figure cannot be given for the pressure on the cloth. Attempts are being made to determine experimentally the "force" of the blow on the cloth to obtain direct comparison between the two types. It was found that variation in the height of the beam or hammers was desirable to allow of different depths of bunch on the beam so that the hammer shaft rests on jacks which may be raised. The blow is heavier than the ordinary wooden faller beetle though this alone does not determine the shortening of the process.

The type of blow is of some importance though precise conditions cannot be stated. The wooden faller beetle blow is characterised by the fact that the main blow (the direct fall of the 60 lb. faller through approximately one foot), is followed by a "bounce" of the faller which rebounds one to two inches (approx.) and falls back on to the beam before being lifted by the wiper beam for a fresh stroke. In the metal hammer machine the bounce is absent and the sound has a different character.

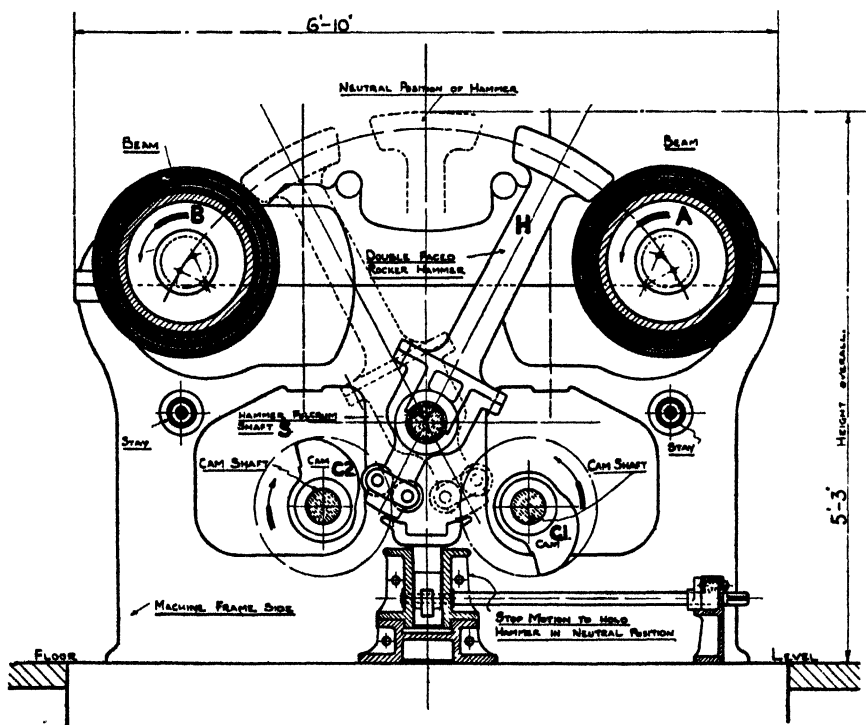


FIG. 3—Sectional End Elevation of Haughton Patent Beetle

It has been shown by Searle⁶ that prolonged beetling of linen fabric may give rise to distortion and cracking of fibres at points most exposed, for example, at the angle where the weft yarn is bent under the warp. This action can be seen in its earliest stages by the appearance in polarised light of the transverse markings of the fibre, which become more prominent. It was found that this action is only pronounced in the later stages of the beetling and it was thought that the shortening of the process on the new machine might eliminate or minimise the action in finishes requiring the equivalent of the longest process on the old

machines. Direct comparison is difficult in the absence of a quantitative estimate but the few examinations made lend support to the view that the shorter process gives less pronounced distortion of fibres.

The overall effect on the fabric is indistinguishable in the finished piece from that given by wooden fallers. This is shown by the results on two qualities (A and B) of linen damask, the same quality was beetled in one case on the ordinary engines and in the other on the new machine.

		Ordinary Beetle		Patent Beetle	
		A	B	A	B
Thickness $\times 10^{-3}$ mm	...	165	198	...	171
Lustre number (G)	...	1.266	1.298	...	1.225
		1.861	1.992	...	1.738
					2.014

It is seen that there is little significant difference between the two finishes. The two figures for lustre refer to the values obtained transverse (the lower value) and along the warp floats. This forms a useful estimate of the "contrast" of the patterns. The slightly greater thickness observed is a fairly definite feature and appears to be related to the time of the operation, apart from other factors.

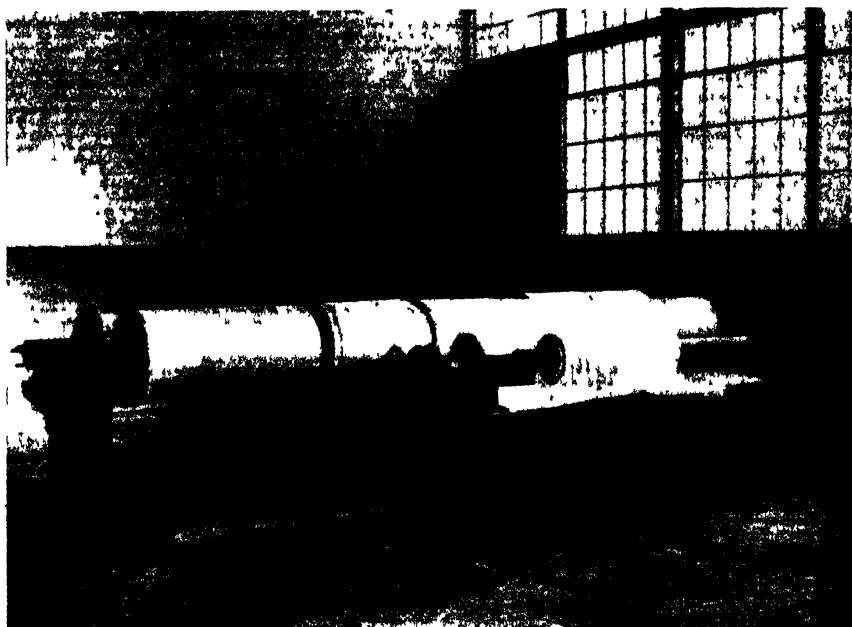


FIG. 4—Stripper

Photo "Belfast Newsletter"

Due to the beetling of two beams at once and the considerable shortening of the process a greatly increased output is obtained. The following figures show the order of this increase—

Output of Houghton Patent Beetle

PRESENT MACHINE

Hours machine actually runs	=111 hours per week
(Including time taken in changing beams) ...	=21½ hours per day
Number of beams beetled, each	=40 per week
Filled with, say, 1 bunch (5 pcs.) dsk. and 3 bunches (9) npks. or equivalent	=approx. 35,000 sq. yards
Time of beetling (2 rounds)—	
First round 2 hours. Second round 3 hours ...	=5 hours per beam
Men working, entire equipment, 2 shifts—	
Two skilled	=£10 per week
Two unskilled	=approx. 0.06d. per sq. yard

NEW MACHINE

Estimated output for the latest design of machine permitting deeper bunches to be beetled and running at increased speeds... ..	=45,000 sq. yards
Number of beams and rounds as above	=approx. 0.05d. per sq. yard

On the wooden faller type, seven engines on an average would be required for an output of 35,000 square yards per week and the direct wages would mean a cost of 0.27d. per square yard.

The power required, 12 H.P., corresponds to the 14 H.P. required for seven engines of the old type. The upkeep charges have been allowed at the same rate as the old type but this has been found so far to be an overestimate.

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- ¹ Patent No. 300,469/28.
- ² C. R. Nodder. *L.I.R.A. Mem.*, No. 59.
- ³ *Textile Manufacturer*, July 1932, 271.
- ⁴ C. R. Nodder. *J. Text. Inst.*, 1931, **22**, T417.
- ⁵ E.P. 284,514/28.
- ⁶ G. O. Searle. *J. Text. Inst.*, 1924, **15**, T382.

THE SCOURING OF LINEN

By E. BUTTERWORTH

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and H. A. ELKIN

(The Gourcock Ropework Co. Ltd.)

Chairman Mr. WILLIAM BLACK

INTRODUCTION

During the scouring of linen, from 20 to 30% of the raw material, purified after normal retting by the mechanical operations of preparing and spinning, are removed by the action of boiling alkali. Although our knowledge of the composition of this alkali soluble component and of its relation to the cellulose of the cell wall is as yet rather vague, the researches of Cashmore¹ and Henderson² following those of Ehrlich and Schmidt³ have shown that the main constituent is a hemicellulose, or rather a group of hemicelluloses, which give, on acid hydrolysis, a mixture of sugars among which were found arabinose, galactose, mannose, and xylose.

This non-cellulosic component is completely hydrolysed and dissolved by boiling dilute solutions of caustic soda. The complex nature of the decomposition of carbohydrates in alkaline solution as shown by Nef and his collaborators^{4,5,6} makes the determination of the course of the reaction by ordinary straight-forward methods practically an impossibility. However, by subjecting the cellulose complex to a graded hydrolysis with caustic soda, much light can be thrown on the removal of the non-cellulosic component. The subsequent examination of the solutions obtained, by electro-conductivity methods, affords strong evidence that a definite reaction is occurring between the alkali and the soluble material.

The method of procedure found to be most satisfactory was to boil green linen fabric, carefully desized and well washed in cold water to remove starch and contiguous impurities, in solutions of sodium hydroxide of various concentrations from 0 to 2.5%. By this means samples of linen were obtained containing various amounts of the non-cellulosic component, determined by estimating the loss in weight during the boil. These samples can then be examined for copper number, viscosity of cuprammonium hydroxide solutions, etc. The alkalinity of the liquors can be determined before and after the boil, thus giving an estimate of the amount of alkali used up.

In this paper we propose to confine our discussion to the consideration of the results of two series of experiments, which we will denote by A and B. For the sake of practical utility we have chosen material of commercial origin, although some of the results have been confirmed using unretted carefully purified fibre examined in other work. The material for series A and B was taken from two different webs so that we are dealing with flaxes of slightly different origin. In series A a liquor ratio of 12:1 was used while in B the ratio was 25:1, thus illustrating the effect of different proportions of alkali to the weight of material for the same concentration of caustic soda.

Details of the methods of experiment and estimation have been described by us already⁷. The results may be considered under three principal divisions. In the first place, the effect of the graded hydrolysis with sodium hydroxide on the removal of the non-cellulosic constituents is examined and the physical and chemical properties of the residual material are discussed in relation to the degree of hydrolysis. Secondly, the relation between the alkali used up in the boil and the dissolved constituents is considered. Finally, we will endeavour to show that strong sorption of the alkali by the residual material occurs and that the amount is largely determined by the degree of hydrolysis.

THE REMOVAL OF THE HEMICELLULOSES etc.

In Fig. 1 curves are plotted showing the effect of increase in the initial concentration of alkali on the percentage loss in weight of the cellulose complex. It will be seen that the loss in weight increases with increase in the initial concentration of alkali. The removal of the non-cellulosic constituent is very rapid at first, 18% being removed in concentration of 0.5% caustic soda, the

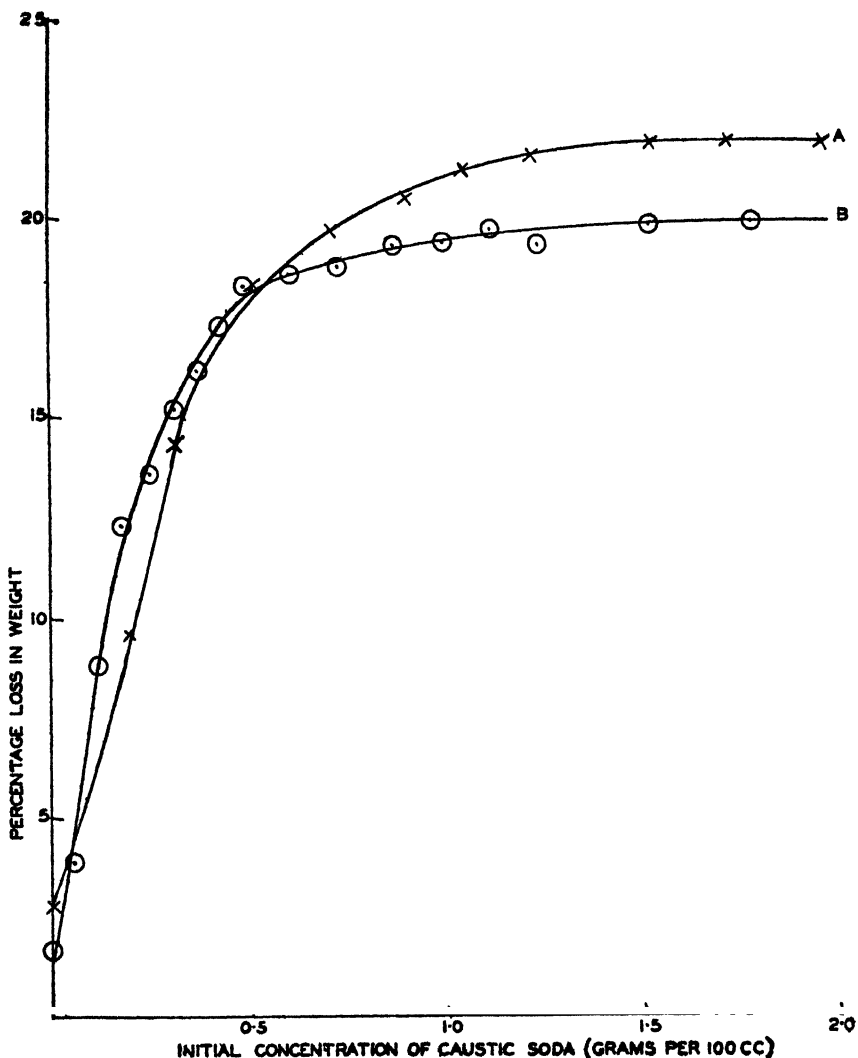


FIG. 1.—Relation between Percentage Loss in Weight and Initial Concentration of Caustic Soda.

remaining 2-4% appears to be much more resistant to alkaline hydrolysis and is not completely removed in the higher concentrations up to 2%. This receives confirmation from practical experience. In the boiling of flax yarns for use in tent ducks or canvas, it is known to be relatively easy to produce a loss in weight of 17% by boiling in solutions of soda ash at atmospheric pressure. If a greater loss in weight is required much more severe treatment is necessary.

The slight difference in the shape of the two curves calls for some little comment. It will be noticed that one of the flaxes contains about 2% more soluble matter than the other. Also, in the former series, the curve rounds off more gradually. This in all probability is due to the lower liquor ratio used in Series A. From Fig. 6 where portions of the curves showing the relation between weight, loss and concentration of free alkali remaining at the end of the boil are plotted, it will be seen that both curves are identical in shape, showing that the weight loss is much more closely related to the final concentration of alkali than to the initial.

The interpretation of the value obtained for the copper number depends on the previous history of the material. Thus a low copper number only means that there is present a small quantity of reducing material and is no measure of the degree of degradation of the cellulose. A high copper number, however, in the case of bleached cotton cellulose does indicate chemical modification. The case of flax cellulose is more complex due to its high content of alkali soluble constituents which exhibit reducing properties. The copper number of a bleached linen material thus affords no indication of the chemical degradation of the cellulose.

An examination of the samples under consideration shows that the copper number (as determined by the Braid method⁸) falls progressively with increasing loss in weight and is more or less a measure of the percentage of non-cellulosic material remaining after alkaline hydrolysis. As the non-cellulosic material is removed the copper number falls relatively slowly at first, the rate of decrease then increases and finally slows up again (see Fig. 2). It must be remembered

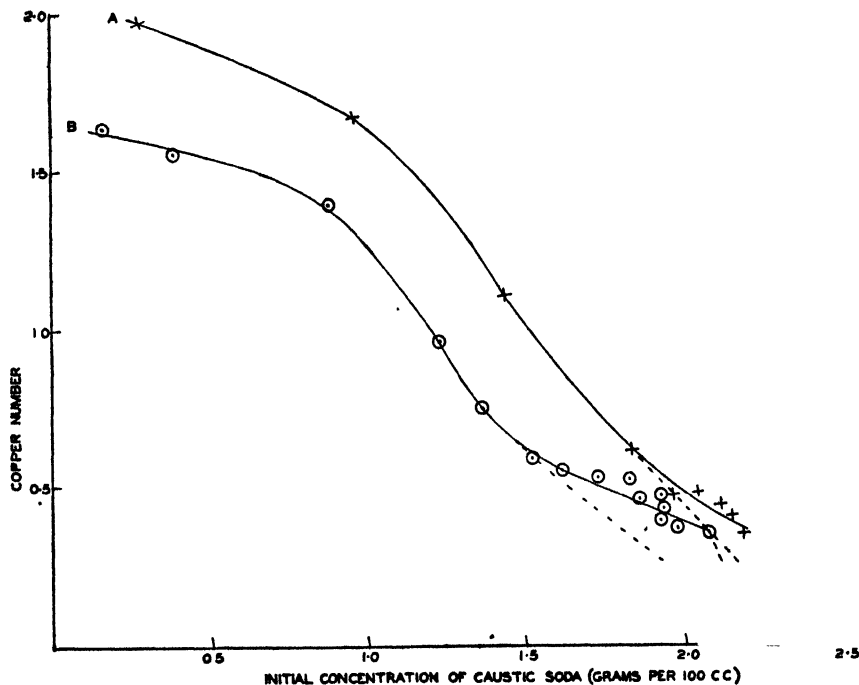


FIG. 2—Copper Number.

that the samples examined, especially in the lower portion of the curve, probably retain some of the more resistant portions of the alkali soluble material or some of it only partially hydrolysed. This tends to keep the copper number high.

Prolonged further hydrolysis in 2% caustic soda, of a material already boiled in a similar solution, reduces the copper number to 0.05 with very slight further weight loss. Thus it would appear that if it were not for the retention of the more resistant portions of the alkali soluble component, the copper number curve would probably fall proportionately to the increase in loss in weight as shown by the dotted line in Fig. 2, but no evidence of the relationship between copper number and any constituent of the complex can be suggested owing to the possibility of partial breakdown in situ of the alkali soluble material during the hydrolysis (cf. Nef and others^{4, 5, 6}).

The determination of the viscosity (or fluidity) of solutions of cotton cellulose in cuprammonium hydroxide is now universally recognised as the most reliable indication of the degree of degradation of the cellulose. Before the method can be adopted for linen cellulose, it is obvious that we must examine the effect of the non-cellulosic material on the viscosity of the solutions. It was found that the viscosity of the complex in cuprammonium hydroxide solution is constant with increasing weight loss. This is illustrated in Fig. 3 (Curve 1). It is a most important point for it indicates that the viscosity of the cellulose complex is independent of the hemicellulose content.

In this series of experiments, the solutions of the samples were prepared in an apparatus following the lines recommended by other workers and previously

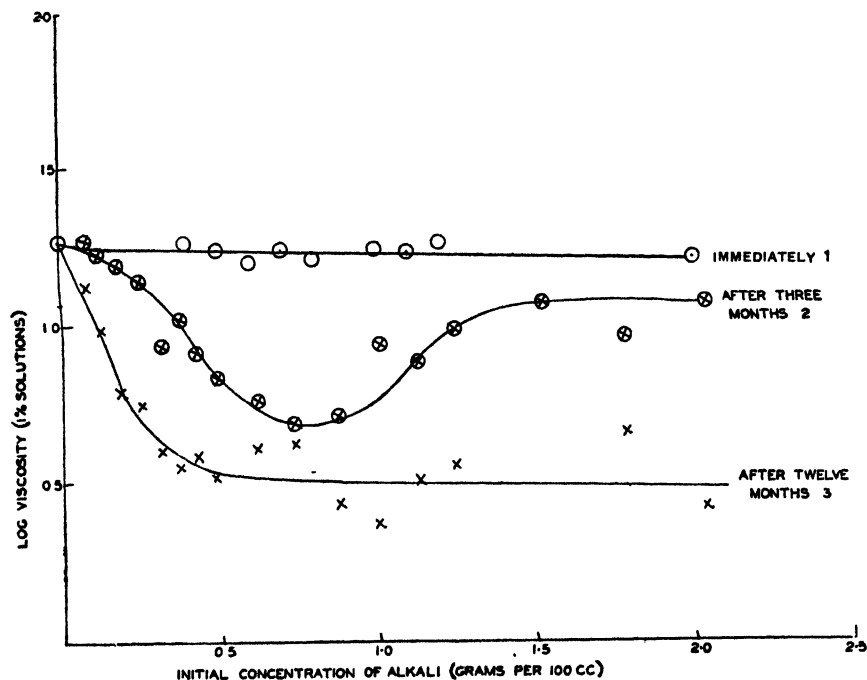


FIG. 3—Log Viscosity of 1% Solutions.

described by us⁷. The only novel feature in the apparatus is the introduction of a sintered glass filter, necessary in the case of the partially hydrolysed material and serving to collect and estimate the proportion of matter insoluble in cuprammonium hydroxide. Even in the samples still containing much of the non-cellulosic component, this insoluble matter never exceeded 5 to 6% showing that the hemicellulose is soluble in the cuprammonium hydroxide. Furthermore correcting the viscosity of solutions to a standard concentration, Farrow and Neale's⁸ modification of the Kendall equation was used and the whole of the

dissolved material was calculated as cellulose. As stated above the resultant viscosity of a 1% solution was constant irrespective of the hemicellulose content. This, however, cannot be taken as conclusive proof of the state of polymerisation of the hemicellulosic component but points to the correspondence of large aggregates in the fibre and large aggregates in the solution. If there is a close linkage between the cellulose and the soluble component, it is probable that they swell as a unit and the resultant viscosity could not therefore be interpreted as definite evidence of the state of polymerisation of one member of the complex.

A most interesting phenomenon was found in an ageing effect on the viscosity of the samples after storage. Fig. 3, curves 2 and 3, show the viscosity of solutions of the samples after storage for three months and six months. It will be noticed that the samples have deteriorated during storage. These samples were not soured after the boiling in alkali and although they were thoroughly washed in hot and cold water, some of the alkali appears to have been retained by the fibre. Subsequent determinations of the alkali by the method of Coward and Wigley¹⁰ showed that up to 0.4% may still be present although the samples were washed until neutral to bromothymol blue. It is to be noted, however, that the peak (minimum) on the viscosity curve 2 corresponds to the peak (maximum) on the sorption curve (Fig. 6, Series B) which suggests a connection between sorption of sodium hydroxide and the ageing effect, causing the fall in viscosity. For the time being, however, no stress can be laid on this point without further evidence.

NEUTRALISATION OF ALKALI

Before returning to a consideration of the function of the alkali in the removal of the non-cellulosic component, brief mention of the experimental procedure may be helpful. Samples of linen were boiled in solutions of sodium hydroxide of known strength. The resultant liquor containing some of the non-cellulosic component in solution was very dark in colour and estimation of the residual alkalinity by direct titration with indicators was difficult and uncertain. A conductivity method was hence employed using a direct reading instrument designed and already described by one of us¹¹. For the sake of comparison, the alkalinity of the liquors before boiling were estimated in the same way.

Two of the electroconductivity graphs obtained from the titration of a sample of the liquor before and after the boil are reproduced in Fig. 4. These curves may be taken as typical of the series. Changes of curvature are interpreted as end points (free alkali or total alkali) and in the figure only the portions representing the significant changes of curvature round the end points are given. The first end point is given by the completion of the neutralisation of free sodium hydroxide, while the final end point represents total alkalinity.

It can be seen that even in the case of the unused solutions (Curve 1) there are two end points. This is due to the presence of traces of sodium carbonate in the solution. With pure sodium hydroxide the lines would meet at a sharp angle. Addition of sodium carbonate to the solution results in the alteration in the shape of the curve after the neutralisation of the sodium hydroxide; at first there is a slight fall in the curve corresponding to the change Na_2CO_3 to NaHCO_3 , followed by a slight rise, indicating the change NaHCO_3 to Na_2SO_4 , to the final end point where a sharp change occurs.

The liquors after the reaction are much more complex and hence give curves which are likewise complex (*e.g.*, Fig. 4, Curve 2). The first end point is distinct in all cases but the second end point is not so sharply defined and can only be estimated approximately. It is obvious, however, that the second (or final) end point corresponds in all cases to considerably less alkali than was originally present, suggesting removal of some of the alkali from the solution by sorption, or combination, with the cellulose and the contiguous material.

The form of the curves indicates that some of the alkali remains after the reaction and the first end point may be read as free sodium hydroxide. (It must be remembered that this is not direct proof of the presence of free alkali, but the slope of the first portion of this curve is the same as that in the case of sodium hydroxide representing the difference in conductivity between OH and SO_4 ions and could be adduced as direct evidence of the presence of free hydroxide). The remaining portion of the curve indicates that a sodium salt of the non-cellulosic component has been formed in the solution. From the alkalinity (free) of the solutions before and after the boil, the weight of sodium hydroxide reacting can be calculated.

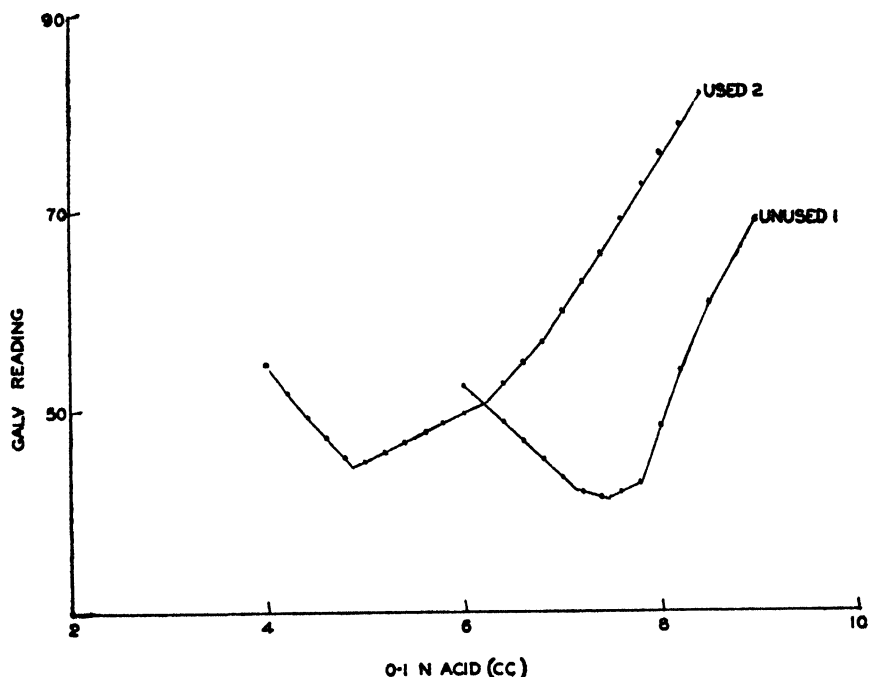


FIG. 4—Electro-titration Curves.

In Fig. 5 the relationship between the sodium hydroxide used up in the boil and the actual loss in weight of the material is shown. It will be seen at once that there is a definite relationship, the curves being straight lines and the ratio of loss in weight to alkali used being a constant. For series A the average value of this constant is 3.4 and for series B the value is 2.8. The slight difference in the values must be due to some inherent difference in the flaxes due possibly to differences in ripeness of the straw when pulled or in the retting conditions. It is hardly possible that the difference is due to the difference in the liquor ratio for this was lower for series A than for series B and if it were to have any effect we would expect to have a lower loss in weight for the same quantity of alkali used and hence the ratio would be lower for series A. On the other hand, for all corresponding samples in series A and B when compared both with initial and final concentrations of alkali, series A suffered a bigger loss in weight than series B and we must therefore conclude that the difference in the ratios is due to a difference in the flaxes.

It is noted that there is a slight falling in the ratio when the most of the alkali soluble material is removed. It has already been indicated that the complete

hydrolysis of the final portion of the non-cellulosic component is more difficult and from the curves under consideration, it appears to require more alkali to bring about the hydrolysis.

It must be remembered that the amount of alkali calculated includes any that has been sorbed or combined and removed from the solution but it is probable that the sorbed alkali will depend, partially at least, on the non-cellulosic component and on its partial breakdown *in situ* and there is hence some justification in including it in the reaction. Precise significance, however, cannot be attached to the ratio at the moment.

The constancy of the ratio lends some support to the assumption that a soluble sodium "salt" is the sole product of the reaction and it would appear that some equilibrium is being attained. This is most probable as values for weight loss can be repeated with fair accuracy on the same material. Furthermore, it can be shown that very little further action is observed with very prolonged boiling. Thus, for example, in a solution of 0.25% Na OH, 6% loss in weight occurs after boiling for 1 hour, 10.2% after 4 hours, and 10.8% after 5 hours. Furthermore, if an equilibrium is being obtained, no further action should be observed when material is again boiled in liquor of alkalinity equivalent to that shown by the end concentration (free alkali) of the first boil. Trials to test this point show that only a slight further weight loss is observed, but that the alkalinity decreases slightly and the liquor darkens appreciably (due probably to the partial breakdown of material in the first boil).

It therefore appears reasonable to conclude that when flax is boiled in dilute caustic soda solution, the loss in weight will depend on the final concentration and on the quantity of caustic soda used up during the boil, the latter quantity being about one-third of the actual loss in weight. In illustration of this it can be calculated that using a 12:1 liquor ratio as in series A and taking the weight

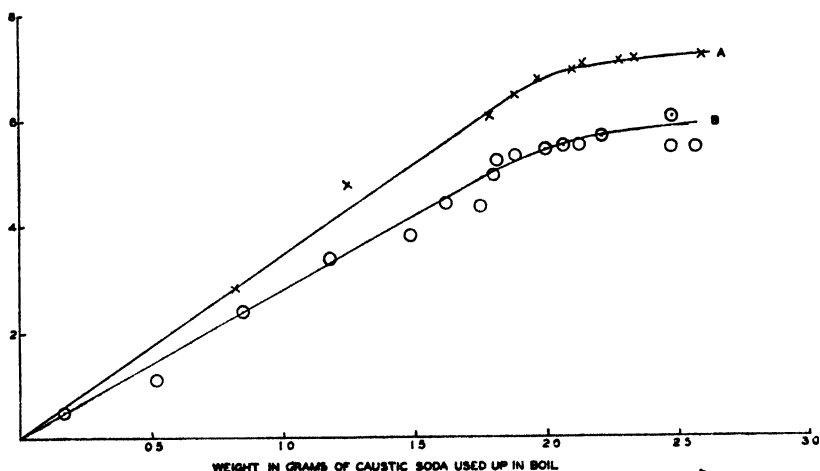


FIG. 5—Actual Loss in Weight and Weight of Caustic Soda used up in Boil.

loss curve of Series B as standard, final concentrations of 0.3 and 0.7% free alkali would be obtained from initial concentrations of 0.9% and 1.3% Na OH respectively. The actual figures obtained in Series A were end concentrations of 0.41% and 0.69% from initial concentrations of 0.9% and 1.22% respectively. Furthermore, when the loss in weight is plotted against end concentration of free alkali as in Fig. 6, the curves for the two series are practically identical, except that Series A has a comparatively bigger weight loss.

SORPTION OF ALKALI

It has already been pointed out above that the final end point, in the electro-titration curve, of all the liquors after the boil indicates a lower total alkalinity than that initially present. This indicates either that the sodium has been sorbed by (or combined with) the material or that the sodium has combined with an acid or other radicle not replaced by a strong acid. The latter is most unlikely and the first is the more probable cause and we will refer to the difference between the total alkalinity after the boil and that before the boil as "sorbed alkali."

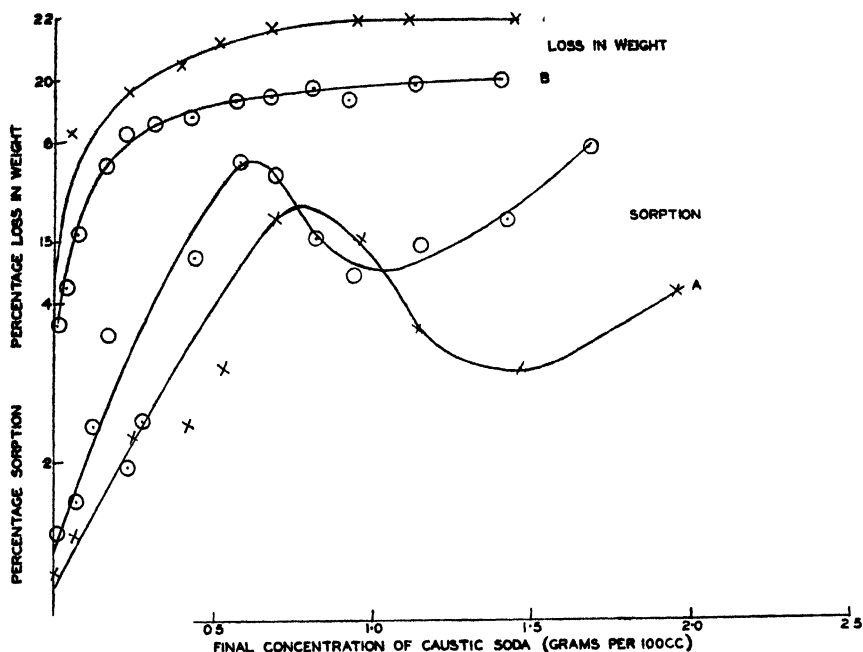


Fig. 6—Relation between Final Concentration of Caustic Soda and Percentage Sorption and Percentage Loss in Weight.

The sorption has been calculated as a percentage of the cellulose complex remaining after the boil, using the relation for the amount sorbed as

$$\frac{100 (p - p_1) v}{g}$$

where g = weight of cellulosic material left after the reaction,

v = original volume of the solution,

p = initial concentration of Na OH,

p_1 = final concentration of total alkali (as Na OH).

This method of calculation has been rightly criticised by Coward and Spencer¹² and for comparison the calculation was made by their more accurate formula, using weight concentrations. With the dilute solutions used, the discrepancies were slight so the above formula was used for the sake of simplicity and convenience.

It must be remembered that although we are referring to sorption, it is, strictly speaking, hardly justifiable in the present case where solution of a portion of the material is taking place. It is more probable that preferential absorption and chemical union of the sodium with the residual non-cellulosic component occur simultaneously.

In Fig. 6 the relation between the sorption and the final concentration of free alkali are shown and it will be at once seen that the relation is most complex, but that the curves for the two series are similar in shape. On the same figure are plotted the curves showing the relation between weight loss and final concentration of alkali and it is to be noticed that the peaks on the sorption curves correspond respectively to the points on the weight loss curves where they flatten out and after which there is very little further removal of non-cellulosic material.

No explanation of the curves can be given at present, although the following tentative interpretation may be put forward. We have already had evidence that the non-cellulosic material (after hydrolysis) is acidic in character and hence has a strong affinity for sodium hydroxide. The sorption, therefore, increases rapidly with increase in concentration of sodium hydroxide until the point is reached when most of the non-cellulosic material is removed. With the final removal of this material the sorption then falls away with increase in concentration until the point when it starts to rise normally again. No further evidence can be put forward at present in support of this interpretation and as already stated it is only tentative.

SUMMARY

The effect of the scouring of linen in boiling dilute sodium hydroxide solutions on its copper number and viscosity in cuprammonium hydroxide solution is discussed. The copper number decreases progressively with increase in loss in weight. The viscosity is found to be independent of the content of non-cellulosic material.

The loss in weight is shown to depend on the concentration of free sodium hydroxide remaining at the end of the boil and to be proportional to the amount of sodium hydroxide used up.

Evidence is put forward suggesting that strong "sorption" of the alkali by the cellulose complex takes place.

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RECENT DEVELOPMENTS IN TEXTILE FINISHING

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The post-war period has been one of remarkable activity in providing new products and new processes for the finishing of textile materials. This is due, to a considerable extent, to the present-day necessity, governed by reasons of economy, for conducting intensive research on the utilisation of bye-products in the chemical industry. This research brought to light many products of interest to the textile trades and it was quickly recognised that in the finishing of textiles lay a neglected field which would amply repay cultivation, and latterly research has been specifically directed to that end.

We see, therefore, that the majority of recent discoveries of this nature has originated, not within the industry itself, but from outside and nearly every branch of finishing has benefited in one direction or another. In spite of the very considerable progress which has been made there are still an enormous number of problems which require solution and we see again, as has been proved many times in recent years, that it is not only the new industries where progress can be made rapidly but our ever-increasing scientific knowledge can be equally well applied even to old established processes and with similar benefit.

A characteristic feature of this development is the enormous number of textile chemical products, over a thousand, excluding dyestuffs, which are actually on the market for use in various finishing processes. These products are designed either to effect simplification in a process or to produce improved, or in some instances, entirely new results on various textile materials. It is significant to find that in spite of some increased cost resulting through their use, many of them have become definitely part and parcel of hitherto long-established operations, and this during a time of intense depression in the textile trades.

The introduction of sulphonated or sulphated fatty alcohols as detergents is one of the most outstanding post-war discoveries in the textile industry. Sulphonation has, in recent years, played a most important part in the preparation of new products for application to textiles. Thus the sulphonation of castor oil provided a soluble type of oil suitable for many finishing processes but which possessed no detergent power and which was not stable to hard water or to metallic salts. The introduction of more highly sulphonated products such as Avirol AH (Böhme) and Prestabit Oil V (I.G.) was a considerable advance, as these products possessed a very high resistance to hard water and metallic salts and could actually be used in heavy Epsom Salt finishes as softening agents. Monopole Soap (I.G.)—a polyricinoleic acid type was another notable advance in the same direction. In 1931, the I.G. introduced Igepon A which is a sulphonated fatty alcohol and about the same time similar products, Gardinols (Böhme) were put on the market. These compounds not only possessed excellent resistance to hard water and metallic salts but in addition possessed an extremely powerful detergent effect, being suitable for washing and scouring all types of textile materials. The discovery of these products will probably revolutionise many textile processes and as their unique properties become more widely known and appreciated, their extended use in the textile industries becomes assured.

A large number of these detergents are already on the market, the most important of which are Igepon A and T (I.G.), Gardinol R and CA (Böhme), Lissapol A (I.C.I.) and the Sulphonated Lorol and Ocenol (Deut. Hydriewerke). Few, if any, of these products are pure compounds but are probably mixtures of sulphonated alcohols of similar type.

The sulphonated fatty alcohols possess the following properties. In addition to being powerful washing and cleansing agents, they are unaffected by acids and alkalis and can be used in hard water, their calcium and magnesium salts

being soluble. They give neutral solutions and do not tend to become rancid. They do not readily felt wool during scouring and they can be safely left in material which is to be subsequently dyed as they do not resist the dyestuff or form scum in the bath but on the contrary exert a penetrating and equalising effect on the dyeing.

In view of these properties, the sulphonated fatty alcohols are being extensively employed in scouring, particularly woollen materials and artificial silks. Some of them are also sufficiently stable to be used in the kier when boiling cotton.

In wool scouring, the facts, that these products possess little tendency to felt the material, that they can be used in hard water and possess no objectionable feature if left in the material, are definitely in their favour and account considerably for their popularity. When dyeing artificial silk their resistance to hard water, freedom from alkali, and their high detergent power allows the material to be processed less severely and in fact dyeing and scouring can often be carried out in the same bath. The material is also given a soft handle which makes the process of additional interest. In the cotton industry their application is also extensive and as an addition to the kier they possess remarkable stability and give an improved white which allows of a milder bleaching treatment, their presence in the cloth not interfering with the subsequent chemicking.

The introduction of these compounds is too recent to allow us to state the exact rôle they will play in the textile industries, but the extent to which they have been already adopted is sufficient indication that their definite establishment as one of the most important of textile chemicals is only a matter of time.

Another class of compounds which has become definitely established in the textile industry is that of wetting agents. The use of soap and alkalis as wetting and emulsifying agents dates back to early history, whilst a more modern development is the use of sulphonated oils for similar purposes. The part which these substances played in the wet treatment of fibres was little understood and even at the present time, in spite of the large amount of research work which has been carried out, much remains to be discovered.

The value of a serviceable wetting agent in the textile trades is evident to all those who have had experience of them. All engaged in the textile industries are aware of the expense, both in time and money, involved in preparing textiles for various wet-treatments and ensuring that they are thoroughly wetted. This wetting is a preliminary to scouring, bleaching, dyeing and to many finishing processes. The use of wetting agents considerably reduces the time necessary for these operations, reduces the temperature at which they can be carried out, and, by producing a cleaner and more thoroughly wetted material, reduces the amount of agent used in the subsequent process.

During the past few years a number of wetting agents of exceptional power and exceptional value have been introduced which are quite different from soap and other old forms of wetting agents. The products on the market may be roughly divided into three main classes. There is first the type represented by Nekal BX (I.G.)—an alkylated naphthalene—sulphonic acid, and Perminal W (I.C.I.), Invadene N (S.C.I.) and others; secondly, the type of highly sulphonated oil or fatty compounds such as Prestabit Oil V (I.G.) and Avirol AH (Böhme), and thirdly, a number of wetting agents are being used for special purposes as for use with mercerising liquors such as Perminal MERC (I.C.I.), Mercerol (Sandoz), etc., which are mostly phenolic compounds.

In order, correctly, to appreciate the value of these agents, their definite limitation must be recognised. They act either by increasing the speed of wetting, by ensuring greater uniformity of treatment or by giving better penetration of the liquid and one or other of these factors is the main reason for using a wetting agent. They may have an indirect bearing upon other processes

but, strictly speaking, this is quite incidental, and one or other of these considerations is of extreme value from the economic point of view or from the point of view of obtaining improved results.

Such old-established processes as those of kier boiling and mercerising have been considerably improved by the use of appropriate wetting agents. In the former case the whiteness of the cloth and its absorbency can be considerably enhanced by their use and in mercerising they are of considerable assistance, especially when mercerising grey material. They have also proved of great value in dyeing, especially when closed machines are used in the package system, a marked improvement in penetration of dyestuff resulting.

Some new emulsifying agents have been introduced within the last few years which are mainly applicable in the wool industry for the preparation of oil emulsions to be used in spinning. Examples of these agents are Nekal AEM (I.G.) and Perminal EML (I.C.I.) both of which are extremely powerful emulsifying agents and possess a distinct advantage over the older type, in that they are resistant to acid, alkali, and hard water. One of the most recent additions to this class of compound is Emulphor O (I.G.), a most interesting product which is of particular value in the preparation of emulsions of oleine for spinning creams. According to the patent literature, this product may be a polyethylene glycol condensation product and if so it opens up a new class of most interesting substances for use in the textile trade.

A further new product Diazopon A may also be considered as a dispersing agent although its main use appears to be to improve the rubbing fastness of azoic dyeings—in which connection it very probably acts through its powerful dispersing properties.

Some years ago a chemically modified form of cotton known as Immunised or Reserved cotton was put on the market. There are at least four different methods of preparing these modified cottons, such as (a) by the action of benzoyl chloride on cotton (Reserved cotton), (b) by the action of *p*-toluene sulphonyl chloride on alkali cotton (Immunised cotton), (c) by treating immunised cotton with ammonia or other amine giving amidated cotton, (d) by acetylating cotton (Cotopa) and (e) by acetylating cotton after mercerisation (Crestol). These treatments result in the cotton losing its affinity for the usual cotton colours and acquiring an affinity for those colours which dye cellulose-acetate. This change produced in the dyeing properties of the cotton fibre may be taken advantage of in several directions. The treatment is usually carried out on yarn which can then be woven with undyed cotton and the material piece-dyed in various shades the immunised cotton being left white. The material may also be piece-dyed to give two-colour effects the untreated cotton being dyed with a normal cotton colour and the immunised cotton being dyed with an acetate silk colour such as one of the Duranol class of dyestuffs. Thirdly, the cotton may be dyed in the hank which is then immunised and woven with undyed material, the whole being then piece-dyed with ordinary cotton colours to give contrast effects. A further minor use for this material is for the marking of garments before dyeing by the garment dyer—the treated cotton being resistant to the action of the dyestuffs generally used for garments. A further and more recent modification of this process was the esterification of cotton in the form of sliver. This was then mixed with ordinary cotton sliver and spun into yarn for fancy effects. Attempts have been made, with varying success, to apply the same process in printing in order to produce localised resist effects. It possesses an advantage over white discharge effects in that the ground colour does not stain the whites on washing.

No review of recent finishing processes would be complete without a mention of the Anti-Crease process developed by Messrs. Tootal, Broadhurst Lee & Co. There is no doubt that a considerable drawback to the extended use of cotton and artificial-silk fabrics in many directions is due to its property of creasing

badly. The anti-crease process recently discovered and patented by Messrs. Tootal, Broadhurst Lee overcomes this defect in a remarkable manner and is a very distinct step in solving a very difficult problem. Previously many attempts had been made to solve this problem, such as by treating the material with certain swelling agents or by impregnating it with stiffening agents, but with little success. It is possible to obtain fabrics with very little creasing property by modifications in the spinning and weaving processes, as by the use of low denier multi-filament yarn or by weaving artificial silk for example in admixture with natural fibres—crêped yarns and fabrics made from them showing a high resistance to creasing. The anti-crease process is, however, the first satisfactory process suitable for treating already woven and dyed material.

The process, as patented, is carried out by the formation of a synthetic resin condensation product actually in the material. According to the patent, the nature of the resin varies according to the material being treated, and examples are given of various phenols condensed with formaldehyde.

An examination of these anti-crease materials show that they are much superior to ordinary fabrics of a similar type which have been untreated. On crushing the fabric it readily springs back again and does not remain in the folded and creased form as does the untreated material. Both cotton and artificial silk or mixed fabrics composed of both materials may be treated by this process with equally beneficial results.

Important, however, as are the results obtained, the anti-crease material on the market is not yet perfect and the process leaves room for still further improvement. The material tends to be removed from the fabric on very severe or repeated washing, when it reverts to its creasable condition and further it is stated that the treated material does not drape as well as ordinary fabrics. These defects may, however, be overcome when more experience has been gained in the large-scale practical application of the process.

One of the most recent discoveries of particular interest to both dyers and finishers, is that of a new fixing agent which has been marketed under the name of Fixanol by I.C.I. The product is an entirely new compound which has been designed for the fixing of direct cotton dyestuffs. It possesses a pronounced affinity for textile fibres whilst at the same time it is capable of combining with direct cotton dyestuffs to produce shades noticeably faster in many respects than the normal dyeings. Direct colours dyed in the normal manner and after-treated with Fixanol are rendered fast to water and acid cross dyeing, perspiration and wet rubbing. The practical advantage of such a range of direct dyeing colours after-treated in this manner is considerable. For the first time one is able to render these colours fast to cross dyeing so that union material need not now be dyed first with acid colours and subsequently stained with cotton colours, but may be burl dyed with direct colours and after-treated with Fixanol first and subsequently cross dyed with acid dyestuffs. By the adoption of this process, in addition to the improved fastness of the cotton material, one is thus enabled to obtain shades much brighter than was hitherto possible. Other uses are with linings of cotton and viscose or of mixture material of cotton and viscose which when dyed with direct colours can be rendered fast to perspiration, rubbing, and water by a single after-treatment with Fixanol. The action of Fixanol is so rapid that warps can be dyed and fixed in the normal machinery for warp dyeing, an immersion of from 1–2 minutes, cold, being all that is necessary to effect perfect fixation of the dyestuff. The range of sulphur dyestuffs can thus be augmented with direct colours after-treated with Fixanol, thus allowing of reds, violets, and reddish-brown shades to be introduced into the range of shades fast to cross dyeing.

It is as yet too early to say how the new process will develop but it is very likely that it will revolutionise certain styles of dyeing and prove of the greatest assistance in many branches of the finishing trades.

Still another entirely new departure is the introduction of a new stripping agent Decamine A (I.C.I.). The methods of stripping hitherto available are based mainly on the action of reducing or oxidising agents which are quite effective for a large number of colours but are ineffective for stripping the majority of the vat colours and quite valueless for stripping the fastest boiling azoic colours or turkey red for example. There exists, therefore, a definite need for a new stripping agent which will attack these extremely fast colours without, at the same time, damaging the material itself.

Decamine A, in the presence of a reducing agent, will strip the fastest of the fast to kier-boiling azoic colours to a white after a few minutes treatment at the boil. Turkey Red can also be readily stripped to a white whilst it is also of considerable value in stripping the fast anthraquinone vat colours. This is the first time an agent of this nature has been put on the market.

The value of a powerful stripping agent which will attack colours hitherto entirely resistant to all normal treatments is evident and this latest development of textile progress will be watched with considerable interest.

A number of other new developments in connection with finishes might be rapidly surveyed in order to illustrate the varied nature of the processes which have been the subject of scientific investigation. The methods adopted for waterproofing have undergone a considerable change in recent years towards a simplified technique involving the use of stable emulsions of paraffin wax with aluminium acetate. Such waterproofing agents allow of a simple one-bath process being carried out and are becoming increasingly popular at the present time. Some new brightening and softening agents for cotton and artificial silk based on the new sulphonated alcohols have been marketed and in addition an anti-felting agent, Perminal NF (I.C.I.) for use with wool has been introduced.

In spite of the many new discoveries which have been made of recent years, there are still many sections of the finishing trade where progress has been slow and where unexpected difficulties have been met with in solving particular problems. In connection with all types of textiles there is a vast field for exploration and there need be no lack of suitable subjects for investigation. The important part played by the finishing trades in capturing the markets of the world are fully recognised and materials are now manufactured with a perfection of finish unobtainable a few years ago and there is no doubt that technical progress will be one of the most important factors in the rehabilitation of the textile industry of this country.

passage through the machine. The rods meeting the cloth are travelling on a comparatively fast-moving chain C. This fast-moving chain has already picked up rods from a vertical chain D. The rod which has met the cloth travels forward on to the chain E. Each rod as it comes on to the chain C makes a fold of cloth. These folds travel across the machine on the chain E, and in time the machine becomes full of folds or festoons of cloth. At the delivery end of the machine the cloth is drawn out by a pair of nip rollers and taken to a plaiting-down or similar device. The rods which have carried the cloth across the machine are returned to the entering end by a down-take and a horizontal chain. All these chains are synchronised so that the rods come into their positions at the required moment. The rods are made of suitable metal (covered if so desired to resist the action of any chemicals which may be used). Above the festoons of cloth which are hanging on the main traverse chain E, a spraying apparatus is fitted. This apparatus consists of a distributing trough of suitable metal with a perforated bottom. The liquor falling through holes at the bottom of this trough passes to a number of spreaders so arranged that the liquor, in passing from one to another, is broken up into fine particles. The liquor on leaving this spraying apparatus is in the form of a fine rain and, falling on to the folds of the cloth, thoroughly saturates and treats equally each festoon and each part of a festoon below it. The liquor falling to the bottom of the machine is pumped through a multi-tubular heater, in which it is reheated to the required temperature and again passes to the distributing trough at the top of the machine. By this means continuous circulation of the liquor at the desired temperature is maintained.

Up to the present the development of this machine has been confined to the delustring process. The machine will scour cotton cloth, and if the temperature in the chamber were raised sufficiently it could be used to take the place of the high pressure kier employed in bleaching. The only modification required to make the machine suitable for this purpose is the addition of a "U" tube at the entering and delivery ends of the machine. With a "U" tube in a machine of this height, a pressure of 7 lb. per square inch could be maintained. The machine would then bottom cloth at a speed well over 20 yards per minute without being cumbersome in size. The above-mentioned facts suggest that the development of this machine may eventually bring about the often-sought-for continuous bleach.

You will have read of, or come into contact with, the Tagliani and Welter machines. These machines were not commercially adopted to any great extent because they were so arranged that the cloth in its passage through the machine had to run over rollers. Rollers cannot be pitched closely together and consequently the lineal content capacity of the machines is strictly limited. Due to this lack of lineal capacity, the machines were limited in speed to such an extent that they were used only partially to treat cloth. The factor limiting the use of these machines has been overcome in the machine described above by the packing of the cloth in festoons. By this means their lineal content capacity is greatly increased. The content of liquor required in these machines is so small that the stability of the "U" tube is much greater than was the case in the older machines. This instability of the "U" tube was a source of serious trouble.

After bleaching, the next development I wish to deal with is that of mercerising. Mercerising had until recently developed on certain conventional lines. A type of stentering machine had always been used as a means to stretch the fabrics whilst they were under treatment with caustic soda. Of recent years attempts have been made, and in some instances with remarkable success, to replace the stenter by other stretching devices. Expanders of different kinds, ranging from the Mycock type of bobbin expander to the oldest type of float expander have been used.

The mercerising range in common use is shown in Illustration 2. This machine in essentials consists of a padding mangle, through which the cloth passes and is impregnated with caustic soda. The degree of concentration of the

caustic soda used is either chosen according to accepted formulæ, or is based on the experience or sometimes caprice of the man in charge of the machine. From this first mangle the cloth is led over a series of drums to another mangle. The drums are used as a means to keep the cloth from shrinking. The cloth, in passing over the drums, is supported by a plain surface throughout its journey between the mangles, and owing to the tension of the cloth on the drums, its ability to shrink is curtailed. The combined lineal surface of the drums is generally arranged so as to amount to about 20 yards. The time the cloth should take before it arrives at the going-out end of the second mangle is approximately 45 seconds.



FIG 2

If it is desired to run the machine at, say, 50 yards per minute, the length of cloth under treatment between the first point of immersion and the point of departure from the second mangle should be approximately 37 yards. This part of the mercerising process is common to nearly all mercerising machines. A modification is to use one mangle and thus shorten the time the cloth is under treatment by caustic soda. Quicker treatment is achieved by suitable preparation of the cloth and by using penetrating agents. The nature of the cloth to be treated determines whether the cloth should be treated on a two-mangle or a one-mangle range. Some cloths will shrink to such an extent after being treated drastically with caustic soda, that by no possible means can they be stretched to their required width without tearing them in pieces or apart from their selvages. In Illustration 2 the cloth, after leaving the mangles, passes over a stenter. Many people place expanders before the stenter, being under the impression that expanders have some innate ability to loosen the fibres, so that when the cloth passes on to the stenter it will stretch more readily. I can see no valid reason for this argument and believe that the use of a stenter following expanders is only a sop to quieten the nerves of people who have heard of mercerising ranges using expanders only, and fearing to depart from accepted ideas are unwilling to discard the stenter in its entirety. In the machine illustrated, the cloth after leaving the mangles commences its stretching process on the stenter. In this process the cloth is stretched to its final predetermined width, which varies from the grey width to as much as 10% or more below grey width, according to the construction of the cloth.

If the theory of mercerising is followed, the cloth should be stretched to its grey width to obtain maximum lustre; it should then be washed clear of caustic soda, whilst under this stretch, to a state wherein the caustic soda concentration will ensure that shrinkage at a rapid rate is no longer possible. To affect this the cloth is sprayed with water, suction boxes being employed to suck the wash water through the cloth.

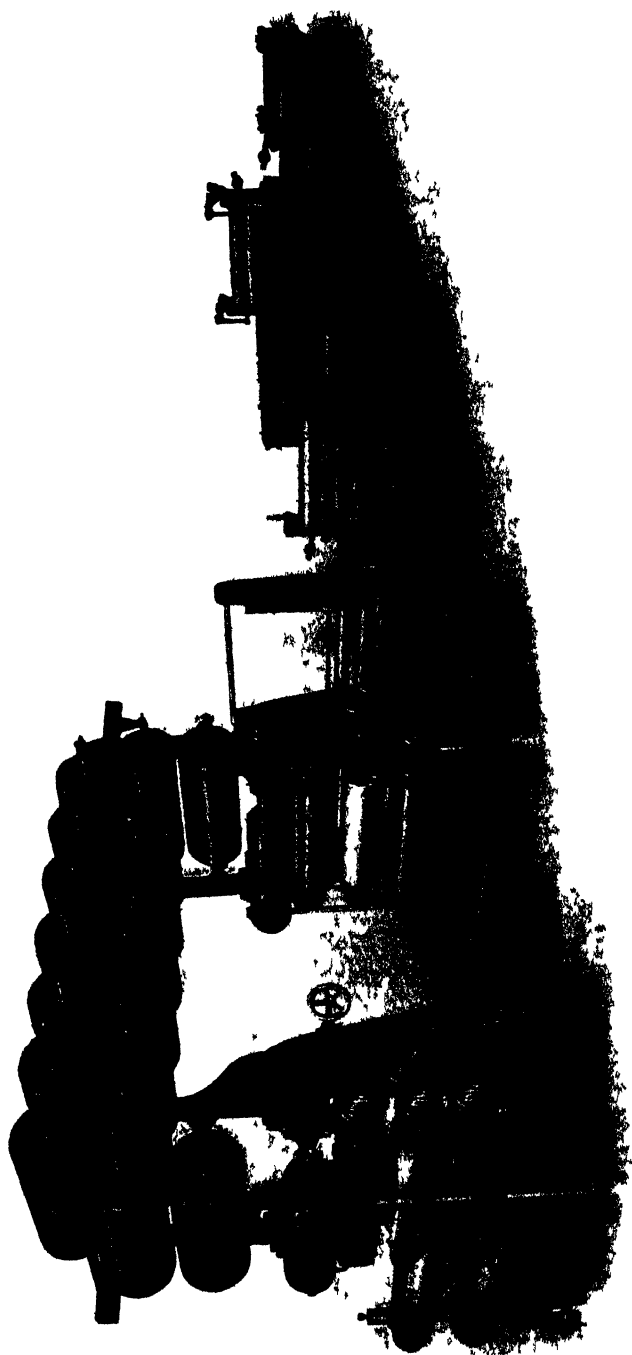


FIG 3

Having now described the process in common use, I wish to show how the latest development in mercerising follows in nearly every respect the old and accepted ideas on mercerising. In Illustration 3 is shown the most modern type of mercerising range using no stenter, but a series of expanders instead. The machine consists of two mangles with a series of drums between them, similar in every respect to those already illustrated, but differing in that both mangles have hydraulic pressure applied to the rollers. Hydraulic pressure is used to obtain greater penetration than hitherto has been customary. The first mangle can be worked at any pressure up to 6 tons across the face, and the second up to 20 tons across the face. By an ingenious arrangement the degree of pressure can be altered at will by simply turning a hand wheel. Both mangles are capable of adjustment in speed relative to one another, so that the correct degree of the desired warp tension can be obtained. This method of speed adjustment I will

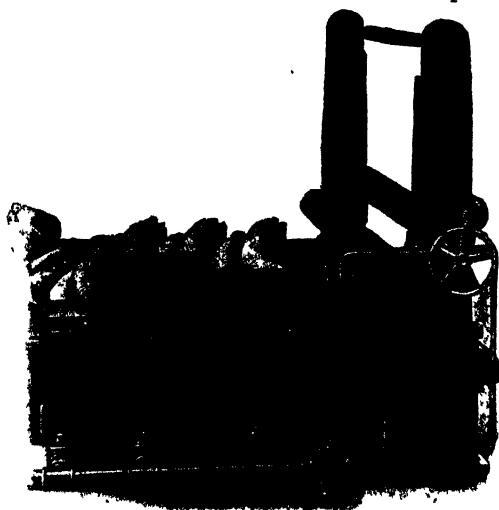


FIG. 4

describe later. After leaving the second mangle and before coming to the stretching arrangement, another ingenious device has been incorporated. This consists of a compensator loaded hydraulically in such a manner that the pressure exerted can be controlled at will by turning a hand wheel. The object of this hydraulic compensator is to exert on the warp of the cloth the tautness required to maintain the warp at its correct grey length. It is a generally accepted theory that mercerising must take place under grey conditions. This hydraulic compensator incidentally enables the amount of bind on the following expanders to be regulated so that the amount of stretch they will exert to the weft can be determined. The arrangement of the expanders is—

Six or eight dry expanders covered with rubber,

Nine iron expanders running under water.

Illustration 4 shows the arrangement of these expanders. The nip at the going-out end of the expanders is sprayed with water. This water flows by a counter current arrangement, so that the most concentrated liquor is at the point where the cloth enters the washing compartment. The concentration gradually decreases until at the last expander it is at its weakest. This expander arrangement is driven through a variable speed device from the preceding portion of the machine. After leaving the washing compartment the cloth follows the same process as on a chain machine. That is, in general, passing through a steaming chamber where the remaining caustic soda is loosened and washed away; the cloth being then treated with sours, or going to the croft as required.

It will be seen from the above that there is very little difference between the chainless machine and the chain machine. The essential difference is the method of stretching.

It may now be asked—why depart from the stenter arrangement? The answer is that the cloth can be worked on a chainless machine super-imposed. Over 30 of these machines have been made and set into work, running at speeds varying from 120 to 160 yards per minute, and in many cases working night and day. You will see, therefore, that the claims for mercerising on a chainless machine are worthy of serious consideration from this point of view alone.

Other advantages of this machine are—(1) Records of all pressures and tensions used on different types of cloth can be kept, and these records can be used so that the same pressures and tensions can be used on similar cloths as they again come to the machine. (2) The controls being simple, it is possible to alter instantaneously the pressures, arranging them to accord with the type of cloth passing through the machine, thus ensuring continuity of working, whatever kind of cloth comes forward. (3) Any kind of cloth can pass over the machine without any adjustment being made. The selvages keep dead to a line from end to end and do not vary, also the width does not vary even as much as on a stenter machine. I know this is a point often claimed against the chainless machine, but it is without foundation. (4) Better mercerising effect is obtained on goods where the warp predominates, because the warp tension is under control on the chainless machine; in this it differs from the chain machine.

The driving mechanism employed in the latest chainless mercerisers is designed to obtain individual control of the various units of the machine, and at the same time to speed up or slow down all the units in unison. To achieve this a motor generator set is employed, capable of generating current of varying voltages. Each unit of the machine is driven by its own individual motor. The motors on the mangles are controlled individually by means of hand-operated rheostats. The motors are set at speeds to maintain the cloth under the correct stretch. The motor driving the expanders is controlled by a rheostat operated from the hydraulic compensator, which in rising speeds up the motor, and consequently the expanders, and which in falling slows down the motor.

The recuperator is driven by a motor, also controlled by a compensator placed at the beginning of the recuperator.

The motors individually or collectively are reversible. If the cloth becomes entangled in any way, it can be drawn backwards by reversing the motor controlling the unit of the machine where the entanglement has taken place. Each motor can work independently of the others.

To speed up the range, the voltage generated by the generator set is increased, and to slow down the range, the voltage is decreased.

It will be seen from the description above that the machine is under absolute control.

After mercerising, the next important development to be discussed is connected with dyeing.

Several dye jiggers have been developed recently to obtain constant cloth speed with minimum cloth tension. To arrive at this object jiggers have been so designed that the speed of the draw rollers increases or decreases corresponding to the alteration in the diameters of the batches of cloth on the two draw rollers; thus a constant cloth speed is maintained throughout the run.

As the let-off roller pays out at the same speed as the batching-up roller takes up, the tension on the cloth is reduced to a minimum.

Illustration 5 shows a patented electric dye jigger which achieves this constant cloth speed by means of a special electric device. As will be seen from the illustration there are two motors driving the draw rollers, one of which is winding up and the other paying out. The cloth tension on this jigger is controlled by a rheostat which diverts more or less current from the pay-out motor. By use of

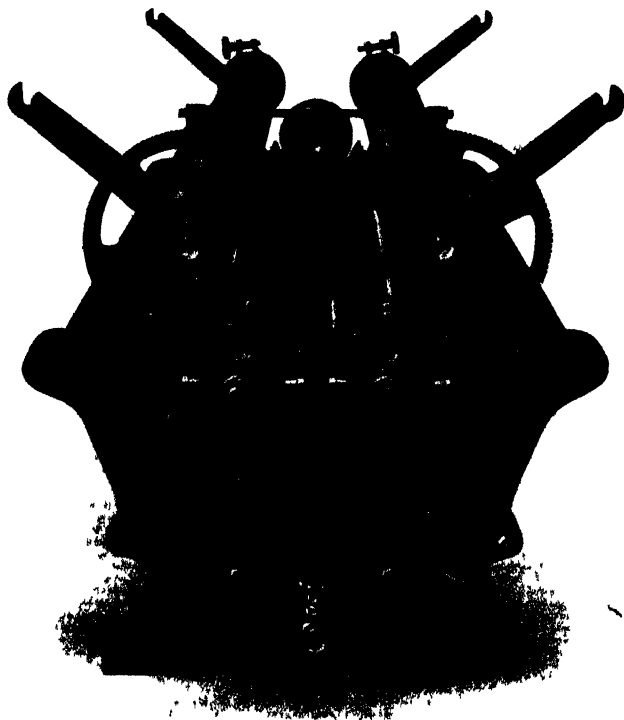


FIG. 5

this electrical device mechanical brakes are obviated. Heat generated by friction increases friction, and in consequence a mechanical brake varies in intensity from moment to moment.

The electrical equipment of this dye jigger is simple and well within the capacity of the ordinary works' electrician.

This jigger enables acetate and viscose silks to be dyed successfully. Real silk crêpes which must not increase in length can also be dyed on it.

The jigger described is specially adapted for the dyeing of large batches of cloth with vat colours. With large batches, cloth passing through vat colours in an ordinary dye jigger would travel so fast through the liquor at its top speed that a rapid oxidation of the liquor would take place. This oxidation is caused by the turbulence of the liquor arising from the excessive cloth speed. The speed at which the oxidation takes place is in the region of 100 yards per minute. When a large batch of cloth is placed on an ordinary dye jigger, unless its minimum speed is too slow, its maximum speed will be well over 100 yards per minute, and consequently oxidation of the liquor will take place. With a constant speed jigger the highest permissible cloth speed can be maintained throughout the run.

This electric jigger can also be operated automatically. The latest method used to achieve this is a photo-cell apparatus, which brings about the reversal of the cloth. The cloth coming to the end of its run exposes a light ray, either through a slit cut in the end pieces, or through the absence of any cloth if strings are used. The light ray acts immediately on the switch gear and the jigger reverses.

With this latest apparatus the cloth has no mechanical operation to perform. The whole of the control gear can be placed well away from the jigger, which is a great advantage.

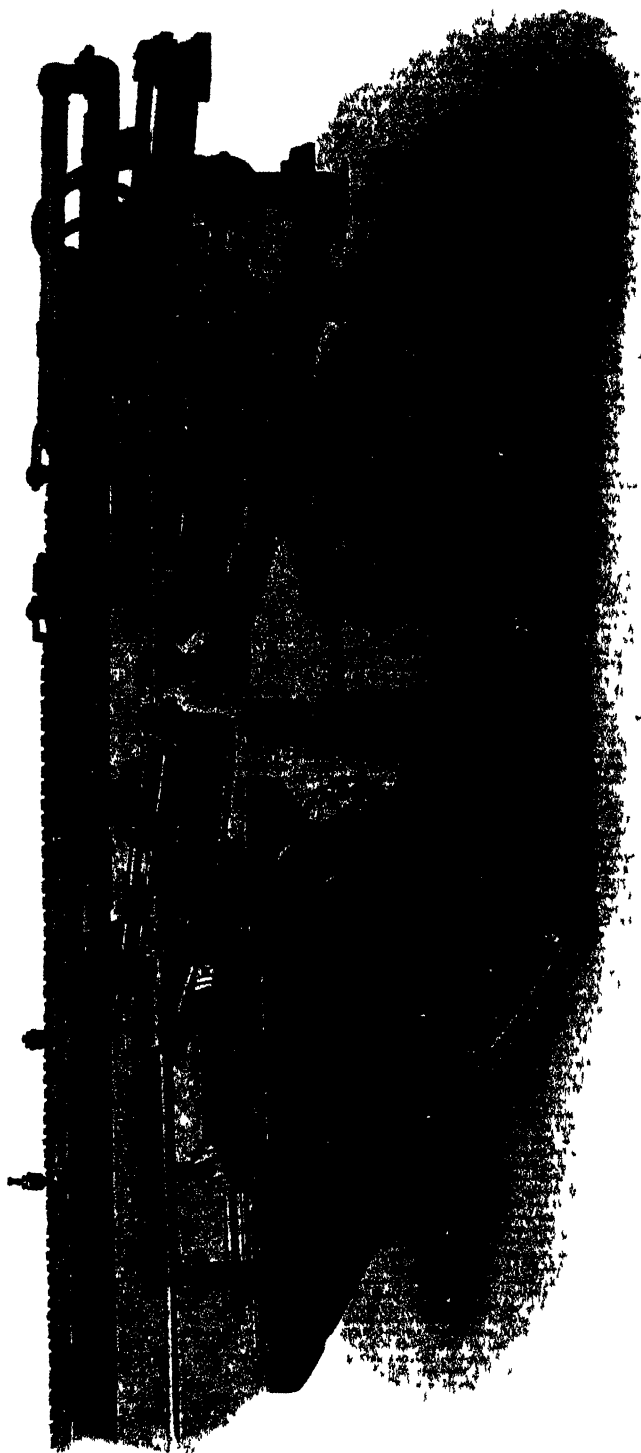


FIG. 9

The whole of the mechanism is mounted on ball and roller bearings. It is totally enclosed and runs in grease, thus no lint or dirt can enter.

By utilising heat-treated nickel-chrome steel for the gearings it has been possible to reduce the dimensions of all gearings to a remarkable degree, so that the whole of the mechanism is very compact and occupies very little floor space. The driving motor is placed underneath the stenter cross rails.

The jiggling motion is now operated by patented hydraulic mechanism (see Fig. 10), which is driven by a separate electric motor driving the gear pump

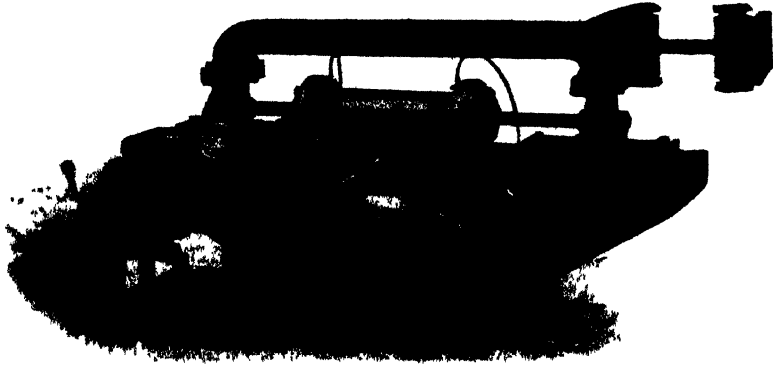


FIG. 10

supplying the oil through special valve gear to a hydraulic cylinder. The piston in this hydraulic cylinder gives the reciprocating motion of the jig. The speed of jiggling can be carried at will from a very low speed to 120 jigs per minute. The length of stroke of the jig can be varied at will by means of movable stops which actuate the reversal of the control valve. An unequal jiggling angle can also be obtained. This infinite range of jig stroke and speed of jiggling makes it possible for a wider range of jiggling finishes to be obtained than was possible with the old type of jiggling motion. This mechanism has been found specially useful for artificial silk to soften down the feel by using a short and very quick jig.

The horse-power consumed by this patent stenter drive is less than 50% of the power required in other types of stenters.

In finishing there have been several developments. The outstanding ones are the production of shrunken goods and two new calendering processes. As the description of the calendering processes is not lengthy, I propose to deal with them first.

Chasing—An arrangement by which multiple chasing can be achieved on calenders working under full load pressure is shown in Illustration 11 attached to a 7-bowl calender. Hitherto when chasing above three or four folds was desired, the pressure exerted on the bowls in the calender had to be very low in order to avoid continuous breakages of the cloth. With the patented arrangement illustrated the cloth may be chased through the calender up to 16 folds under full pressure. The calender will run continuously without stoppage. Compensator rollers are placed between the folds of the cloth to take up the increase or decrease in the length of the fabric caused by the calendering process.

To keep the compensators under control each fold of cloth as it passes to the first nip of the calender is run through adjustable stave rollers. These rollers can be adjusted to increase or decrease the cloth tension according to climb or fall of the compensator rolls. Each of the rollers marked A is adjustable in height and by suitable adjustment the cloth can be kept straight in its passage over the compensators.

With this arrangement calenders are running continuously, without re-threading, day in and day out, at speeds up to 160 yards per minute. This multiple

chasing apparatus produces excellent closing finishes unobtainable by any other calender process, and enables many hydraulic mangle finishes to be imitated in a continuous manner at high speeds. Calenders fitted with this multiple chasing apparatus and with all cotton bowls and no metal bowls will give a close imitation of a beetle finish. When such a beetle calender is used correctly, the difference between the calender and the true beetle finish can only be detected by close expert examination.

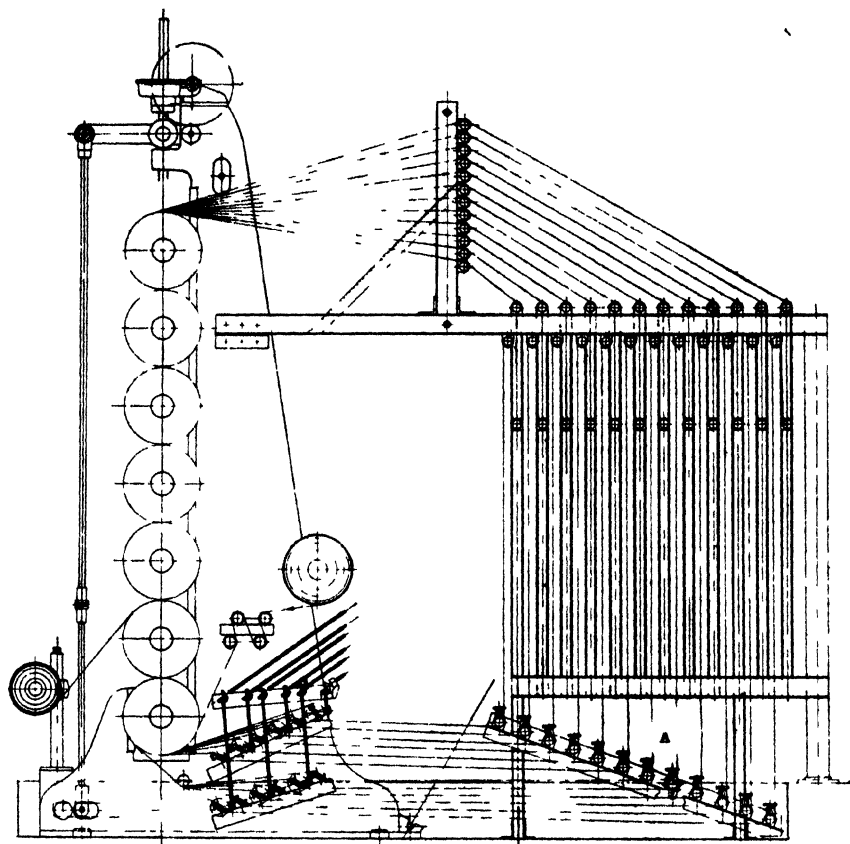


FIG. 11

The calender illustrated in Fig. 12 is designed to enhance the lustre of mercerised goods and to impart to them a top finish or super-imposed lustre.

The cloth passing in a dry state through a nip does not accept the permanent crushing usual when wet. The cloth receives the polishing effect, but owing to its dry condition springs back to its normal liveliness and is not flattened. The low parts are polished like the high parts, and the cloth shows a finish similar to that obtained on a high-class cloth when mercerised.

The calender is fitted with a pump and accumulator used in connection with hydraulic cylinders placed underneath the bearings of the bottom bowl.

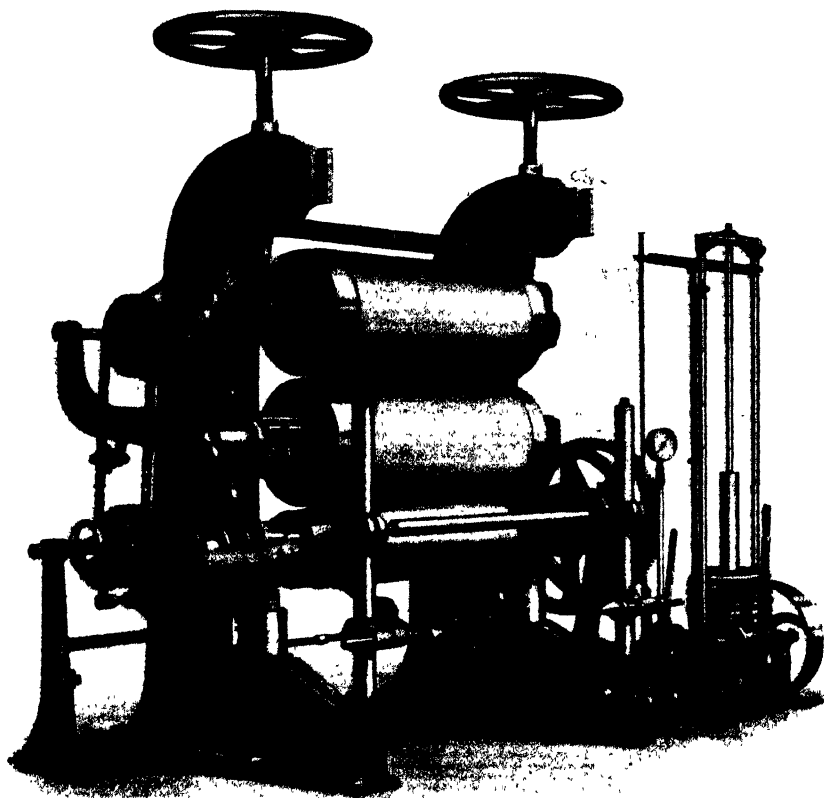
The arrangement of the calender is—

Top bowl—cotton.

Middle bowl—cotton.

Bottom bowl—chilled iron steam-heated.

To prevent the possibility of slipping, the top bowl is driven by an arrangement of chain wheels and a slipping disc clutch attachment.



The chilled iron bowl acts as a bed bowl for the cotton bowls and keeps a polished face on the surface of the cotton bowls.

The cloth passes over two or three drying cylinders attached to the calender and is passed between the cotton nip only. The cotton bowls are of a very resilient nature and impart a finish to the cloth on both sides without crushing the texture of the cloth.

I now propose to describe one of the methods adopted to produce pre-shrunk goods.

Cloth in its progress to a finished article suffers distortion both in warp and weft. When finished cloth is made up into clothing, unless it has been correctly preshrunk, it still retains the distortion acquired during the finishing process. Cloth forming a garment will regain its natural state when it is washed, and the garment will alter in dimensions in proportion to the distortion which took place in the cloth during the finishing process. To overcome this habit garments have of assuming another set of dimensions when they are washed, preshrinking has come into vogue.

The particular process of preshrinking I propose to describe is the one known as "sanforising." In this process a standard sized sample of the cloth to be treated is given a normal laundry wash test, and the shrinkage in warp and weft is noted.

The sanforising machine, Fig. 13, used to preshrink cloth, is so set that the cloth when leaving the machine assumes a state wherein its warp and weft have shrunk to a required degree. This required degree is in proportion to the shrinkage which took place in the sample treated by the wash test.

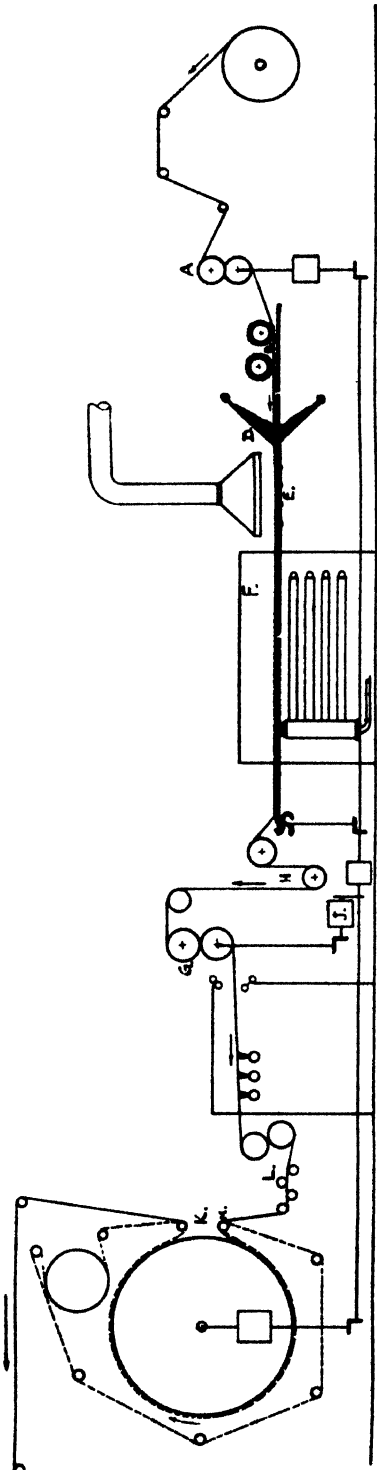


FIG. 13

The sanforising machine consists of a stenter machine and a modified Palmer machine. The cloth to be treated is entered in the open width into a pair of nip rollers A and fed by them on to the pins of the chain at a speed faster than that of the chain (B); the difference in speed between the chain and the feed rolls being equal in inches per yard to the length of shrinkage per yard which is required. To achieve this the feed nip rollers A are driven through a change speed gear box with 15 change speeds, each speed arranged to equal $\frac{1}{4}$ in. When the control handle of the gear box is at zero, the gear box drives the rolls at the same lineal speed as the stenter chain, and each stop equals $\frac{1}{4}$ in. per yard of shrinkage, so that in all $3\frac{3}{4}$ in. shrinkage is obtainable.

The cloth is fed from the feed rolls on to a pin chain with pins so arranged that the extra length of cloth fed onto the pins is accommodated in between the pins. The pins are pitched $\frac{3}{16}$ in. apart in double rows, resulting in an actual pitch of $\frac{3}{8}$ in., thus no unevenness is noticeable when the cloth becomes taut. The cloth, which is now on the stenter pins in the desired superfluity, is subjected to a heavy spray damping D, and a good steaming E, consequently it shrinks and becomes taut on the pins. As the chains carry along the stenter, the cloth passes through a hot chamber F, where it is dried. The cloth leaving the stenter has undergone a virtually correct length shrinkage. The width of the stenter is so set that approximately correct width is obtained.

At the going-out end of the stenter, the cloth is drawn from the stenter by a pair of nip rollers G, so arranged that the cloth is subject to no warp tension. To achieve this the rolls are controlled in speed by a very delicately balanced compensator H, which with the slightest cloth tension adjusts the speed of the rollers through a variable speed drive J.

It is now necessary exactly to set the width of the cloth and any lengthening of the warp due to the setting of the width must be adjusted. This is achieved on the modified Palmer.

The cloth in passing between the stenter and the Palmer is subjected to a slight tension, about a 6% speed increase, and is treated with a water spray and steam. The cloth both shrinks slightly in width and lengthens in warp.

Before entering the Palmer H, the exact required width is obtained by a pair of adjustable expanders L.

The final adjustment of the warp is now to be obtained.

The degree of shrinkage obtainable is determined by the diameter of the

blanket roller and the thickness of the blanket. If the shrinkage determined by the above factors is greater than is desired, the Palmer must be increased in speed so that the cloth is stretched more. If the shrinkage is less than desired, the cloth must not be stretched so much. The means with which shrinkage on the Palmer is obtained is a very novel arrangement, and very simple.

If we consider Fig. 13 it will be seen that the surface of the belt in contact with the large drum assumes the same speed as that of the drum.

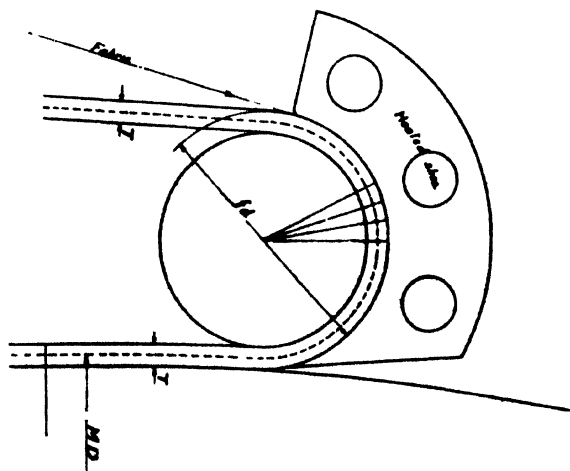


FIG. 14

The material having passed through the adjustable scrimp bars L runs on to the belt at K, passing over a small revolving roll M and thence between the blanket and the drum. The speed of the fabric is that of the outside of the blanket when on the roll, and that of the inside of the blanket when touching the drum. In Fig 14 if—

md = the mean diameter of the blanket on the roller $2\frac{1}{2}$ in.
 T = the thickness of the blanket $\frac{1}{4}$ in.
 fd = the diameter of the outside of the blanket on the roll on to which the fabric is fed 3 in.
 d = is the diameter of the roll $2\frac{1}{2}$ in.

During one revolution of the roll—

the blanket moves — $md \times \pi$

fabric moves = $fd \times \pi$

The difference between the movement of the blanket and of the fabric = $T \times \pi$

The number of revolutions the roll makes before outside of the blanket traverses a yard is—

$$\frac{36}{fd \times \pi} = \frac{36}{\text{circumference of the roll and blanket}}$$

In a 1 yard movement of the blanket, the difference between the movement of the blanket and of the fabric—

$$= \frac{36}{fd \times \pi} \times T \times \pi$$

that is to say, an extra quantity of cloth is delivered between the flat surface and the blanket by this amount, namely—

$$\frac{36}{fd \times \pi} \times T \times \pi$$

Substituting the values given above we get—

$$\frac{36}{3 \times \pi} \times \pi T \times \text{that} = \frac{36 \times \frac{1}{4}}{3} = 3 \text{ in.}$$

It will be seen, therefore, that 3 in. of extra cloth is crowded into a yard of cloth or mechanically shrunk. The cloth is made to adhere to the surface of the blanket by a light pressure from electrically heated shoes, which are placed side by side in short sections of about 4 in., extending over the full width of the machine.

The cloth, as we have seen, is fed at a higher lineal speed than the surface of the drum is making, and if these heated irons were not there to prevent it, the cloth would pucker up in folds. The irons prevent this puckering, and consequently the threads are closed together mechanically.

As will be seen from the above calculations, the maximum warp shrinkage, using a $\frac{1}{4}$ in. blanket and a $2\frac{1}{2}$ in. diameter roll, is 3 in. per yard, but as the cloth now is almost correctly shrunk, we do not wish, in most instances, to avail ourselves of the whole of this obtainable 3 in.

In order to obtain the required amount of shrinkage, the Palmer is made to run faster than the cloth is fed to it by the stenter. This is in the neighbourhood of 6%, as has been mentioned earlier in this paper.

The tension on the cloth causes the cloth to slip back under the shoes, that is, not to travel as fast as the blanket. If the cloth were allowed to travel at the same speed as the blanket, a 3 in. shrinkage would take place.

The cloth now passes round the drum between the blanket and the drum and thereby obtains a fine finish.

Owing to the possibility of shrinkage by mechanically crowding of fast running cloth on to a slower running receiver, under pressure, it will be seen that a machine designed to make use of this mechanical crowding can serve as a shrinking machine without the addition of a stenter. In some instances a Palmer can be used as a shrinking machine, without the usual accompanying stenter.

FULLING AND MILLING MACHINERY

By E. KILBURN SCOTT, M.Inst.E.E.

Chairman Mr. FRANK NASMITH

PART I—FULLING STOCKS

In two of the main streets of Pompeii there are well-preserved fulleries, with numerous places where the men stood when "walking" the cloth. On the wall of the principal one, there were found well-drawn coloured pictures, showing fullers at work. They are now in a museum at Naples. In the House of Vettii there were also pictures showing fulling.

Some cloth makers who came with the Roman army to Britain in the first century, established the art at Winchester, and from there it spread wherever the Roman legions were settled. Probably the first Yorkshire, that is, Brigante, women to wear skirts of cloth instead of skins were the wives of centurions stationed at York.

Near a Roman villa at Darenth in Kent, some small rooms were found on the side next to the river which puzzled the antiquarians, but I saw in them a domestic fullery and laundry. No doubt most of the large Roman villas were similarly equipped.

Practically all mechanical advances have originated from man's desire to save himself from arduous work, and so it may have occurred to tired cloth-walkers of Greek or Roman times to imitate the action of their feet by beaters. Pliny says that fulling was carried on at Megara, the industrial town in which Euclid lived. Certainly the Arabs knew about fulling, for a very ancient machine like a fulling stock was found at Ferboubra.

There were fulling and teazling mills in Gloucestershire in 1175 A.D., and so long ago as 1369 Langland wrote of fulling stocks in "Piers the Ploughman" thus—

"Cloth that cometh from the Weyvng
Is nought comely to wear
Till it be fulled underfoot,
Or in fulling stokkes,
Washed well with water,
And with teazles cracked."

Several drawings of fulling stocks appear in German and Dutch books of the eighteenth century,* that of Leupolds showing the feet falling vertically. A book called "The Experienced Millwright," published by Thomas Gray in 1806, shows a fulling stock made of wood, with the feet at about the same angle as present day machines. He also shows a machine for scouring or washing cloth, which has the feet moving more nearly horizontal; curves of the "turn" are given.

Machines built so recently as the beginning of the last century had the tappit shaft made of a tree which ran in journals of hard wood lubricated by a mixture of fat and plumbago. The end of the tree usually carried the waterwheel. Some 30 years ago, whilst reporting on hydro-electric power at Dalgargog in North Wales, I saw such an ancient mill.

The oldest fulling stock still at work is in the Vale of Conway woollen mill, and it was made by my great grandfather, William Kilburn, who died over a century ago. There used to be several of his stocks in Booth's mill, at Gildersome, and nearly half a century ago I helped to repair one of them.

William founded the business at Holbeck bridge in 1810 when 34 years of age, and his brother John went to Meltham to do the same. They had both been with Matthew Murray, from whose works came many early pioneers of engineering.

Five sons worked for him, and when James, the eldest, went to Russia about 1835 to equip a cloth mill for Count Poniatowski, Richard Kilburn took over the control. In 1865 he built the present works in Elland Road.

* Recently I have discovered a good illustration of fulling stocks in an Italian book published in 1656.

The iron foundry, managed for about half a century by R. Kilburn, junior, is of some interest to cloth makers because of the partnership deed of 1772, signed by Titus Salt. His son Daniel was the father of Sir Titus, the first to make alpaca, and founder of Saltaire.

The tappit wheel shafts for stocks cast there were largely of old iron guns melted in an air furnace instead of a cupola. They were hexagonal in section, about 6 inches across, and we made the beds for keys by hammering down projections. In some cases the tappit wheels were fastened in ancient millwright fashion by packings of dry oak and steel wedges.

Proportions of Stock

English oak necessarily forms a considerable part of a stock, being fastened to the castings by oak pegs, made from old cart wheel spokes. Clearances are nicely adjusted so that the cloth cannot get nipped between the feet and the sides. When the stock is not in use, the feet are caught-up by stangs made of ash. The "turn" is a large piece of solid oak cut with special curves to make the cloth move round a little at each blow. See Fig. 1.

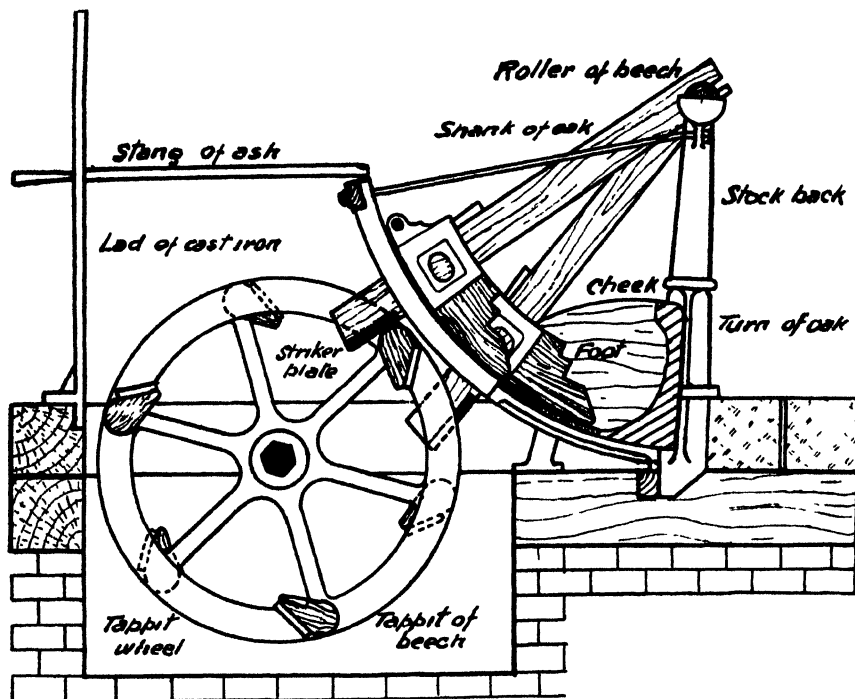


FIG. 1—Fulling Stock, showing names of parts and materials of which made.

NOTE—The shaft runs at about 13 r.p.m. so that each foot strikes 40 blows per minute.

Weight with shank and striker plate = about $2\frac{1}{2}$ cwt. each foot.

As there are six tappits on the wheel, and the shaft runs at about 13 revolutions, each foot gives 40 blows per minute. It is not possible to give more with a gravity stock. A foot of solid oak weighed about $1\frac{1}{2}$ cwts., and of cast-iron shod with oak, about $2\frac{1}{2}$ cwts., including the shank and striker plate.

The box is usually about 2 ft. wide, and the amount of cloth put in varies from 60 to 120 lb., or 10 to 20 wartens. To operate with a lesser quantity, a "went" is attached to the top of the turn.

The rollers which carry the ends of the shanks are of beech, and they require renewal every year or so. A note-book of Richard Kilburn, dated 1852, gives the following names of millwrights, and of the sizes of rollers they used.

	Diam.	Length
Joseph Pickles of Stanningley	7 in. ...	19 in.
Withams of Kirkstall	6 in. ...	19½ in.
Joseph Bottomley & Sons of Bramley ...	5½ in. ...	20½ in.
Wm. Fothergill & Cardwell	5½ in. ...	19½ in.
J. Hirst of Gomersall	5 in. ...	19 in.
Greenwood, Day & Fox of Ravensthorpe ...	8 in. ...	22½ in.

Other millwrights were Lumb & Leeming Webster of Leeds; Asquith of Morley and Hopkinson of Dewsbury, former apprentices of my grandfather; Timothy Bates of Sowerby Bridge; B. Preston of Batley; J. Sykes of Huddersfield; James Hustler of Bradford; and Mitchell of Brockholes.

Power Required

When cloth is freshly loaded into the box of a stock, the distance it turns at each blow of the feet may be about 2 inches, but when the soap has permeated, it lubricates and the movement may be 4 inches or even more.

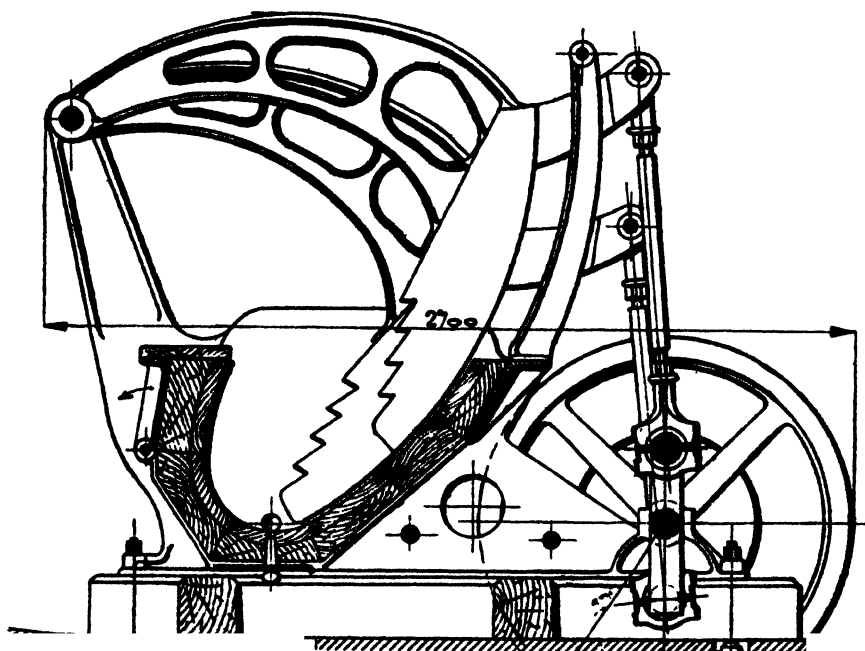


FIG. 2—Crank type of Fulling Stock taking 110 lb. of cloth. Runs at 100 r.p.m. and requires 8 h.p.

NOTE—The shanks are curved to leave head-room for the milner. The top part of the "turn" is hinged.

Assuming the weight of the foot at 2 cwts., the lift at 3 ft., and the efficiency of the gearing at 80%, the power required to work an ordinary stock works out at—

$$\frac{80 \times 2 \times 112 \times 3}{33,000 \times 0.8} = 2 \text{ horse-power.}$$

Again, assuming that the stock foot travels 3 inches after first striking the cloth, the pressure exerted may be approximated as follows—

$$\frac{2 \times 112 \times 3}{0.25} = 2,688 \text{ lb., or say 24 cwts.}$$

In stocks the fulling action is necessarily slow, but it is thorough, going right through the fabric in a way that is not possible with milling machines. One great advantage of stocks is that they do not make mill-riggs, and for that reason they are frequently used to stop creases which have begun to form in the milling machine.

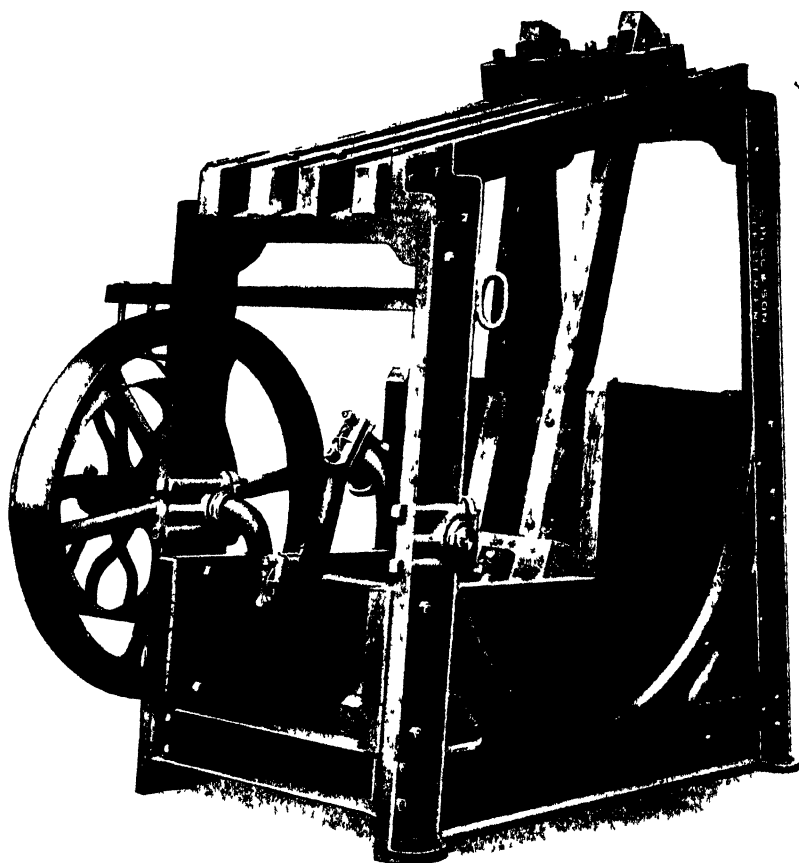


FIG. 3—Crank Fulling Mill by Samuel Pegg & Son, Leicester

NOTE—The flywheel on the left and the wooden supports for the bearings of the shanks.

For coloured fabrics of delicate shades, stocks are useful owing to the temperature being moderate, and there being less possibility of "bleeding" colours. It is, of course, possible to apply steam heat to the box, in fact that was done over a century ago by the famous "Billy" Hirst of Leeds. Moving pictures taken by Professor A. F. Barker in Kashmir show a man "walking" shawls on a heated stone to hasten the fulling.

Crank-driven Stocks

In early days there was a machine, called a "Driver," in which the feet swung horizontally, being driven forward by the spokes on a shaft. It was not so good because of the forward movement being limited. Early crank stocks also had this fault, but on the other hand they gave many more blows per minute.

One of the first to make provision for varying the capacity of the box was B. Preston, who did it by changing the position of the crank. A design by B. & D. Wright had telescopic connecting rods with springs inside.

Excellent crank stocks made by Mitchell have the "turn" or back of box mounted on slides. By means of strong screws it can be advanced towards the feet as the bulk of the cloth becomes less. Each foot gives 150 blows per minute. The top of the turn is hinged, and there are doors on each side of the box to facilitate getting cloth in and out.

Fig. 2 shows a crank stock with vertical connecting rods and curved shanks to provide plenty of head room for the milner. Fig. 3 is typical of those used for fulling knitted woollen goods in Leicestershire, the boxes of which take four dozen garments at a time.

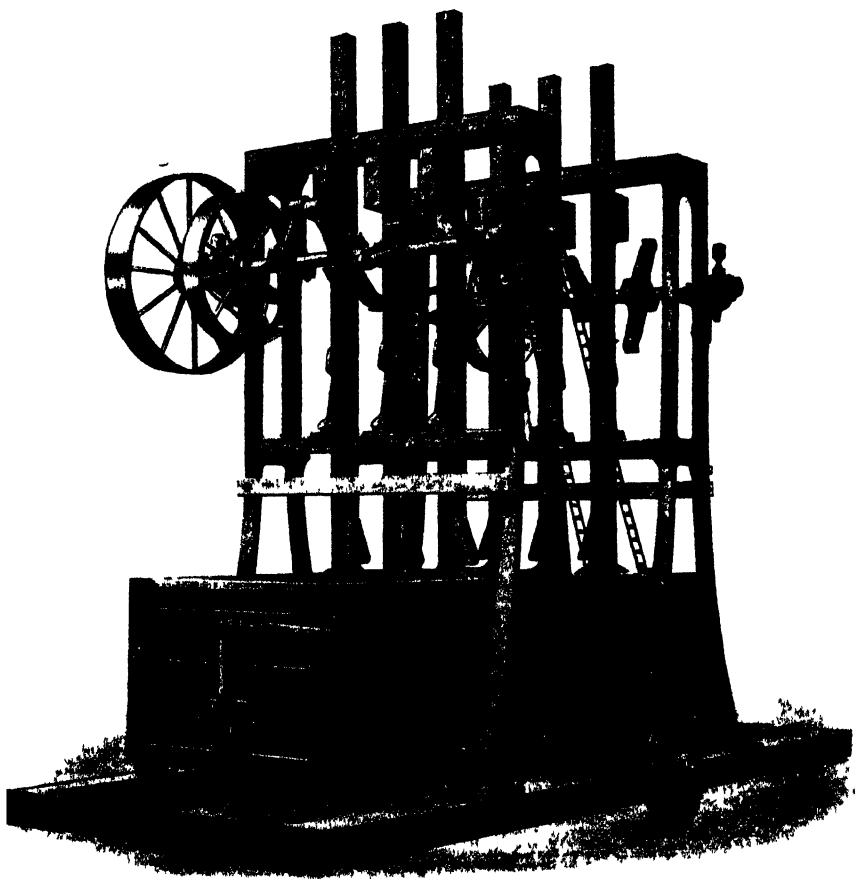


FIG 4—"Tom-tom" Machine, used for scouring and fulling knitted woollen goods
NOTE—Beater cams and reciprocating gear

Knitted goods manufacturers use a machine called a "Tom Tom," shown in Fig. 4, in which beaters are lifted by cams. Each delivers about 90 blows a minute, and the trough with the goods in it, reciprocates back and forth once every half minute. This is effected by a pinion engaging with teeth or pegs on the side of the trough.

Stock With Lifting Chains

One disadvantage of the ordinary stock is the relatively large space occupied by tappet wheels and accessories, and the heavy foundations required to minimise

vibration. To overcome these disadvantages, Savage & Padgett have introduced a design in which the tappit wheel is replaced by heavy Ewart chains which run over cut sprocket wheels set about 3 feet apart. The chains carry bars that, engaging alternately with the ends of the shanks of the feet, lift them up.

To reduce vibration and noise, the back portion of each foot is fitted with a coil spring $2\frac{1}{2}$ in. in diameter and a foot long, to take up the force of the blow each time the foot is lifted by its respective bar. I have seen them operating in a blanket factory, where they perform very well.

Owing to the modern desire for greater speed of production and lighter goods, the future for fulling stocks for cloth is not good. They are, however, used for other purposes as, for example, in the manufacture of felt hats. The machines are usually built in a battery, as shown in Fig. 5.

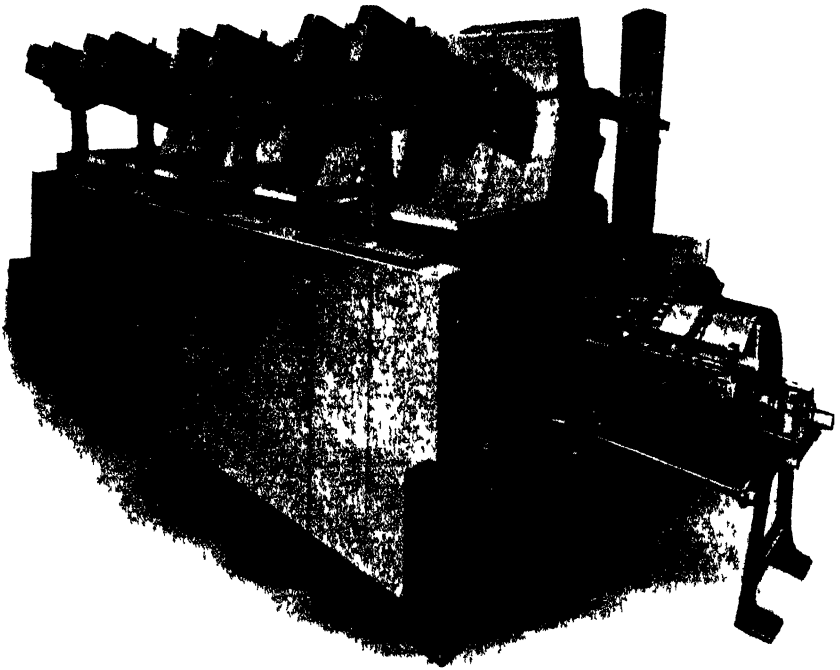


FIG 5—Kilburn Bumpers as used in Denton-Hyde district for fulling hats. They are made for 4 or 6 dozen $5\frac{1}{2}$ -oz. hats at a charge.

NOTE—Feet made of oak, which used to be practice with ordinary fulling stocks.

Another use for stocks is to soften hides, particularly those hard kips that come from overseas. They are built entirely of iron and the feet weigh about $3\frac{1}{2}$ cwts.

PART II—ROTARY MILLING MACHINES

The rotary form of machine came into use because after the industrial revolution many people began to wear cheaper and lighter weight clothing. A machine was required which could work continuously and quicker than the old fulling stocks, take up less room, and have practically no foundations.

These conditions were met by John Dyer, of Trowbridge, who devised a rotary form of machine which he patented in 1833 and 1838. Naturally it was first used in the West of England, and it is of interest to note that some of his machines, with ungeared top rollers, were in use up to about 30 years ago.

The late Mr. Fred Kilburn told me that the first rotary milling machine which he saw was in Taylor's mill at Batley, and it was called a "Chevalier." There may have been some connection with Chevalier Claussen, who was an expert in textiles. He is mentioned in "Arts and Manufactures of Great Britain," by C. Tomlinson, F.C.S., as having in 1851 introduced a method of preparing flax to give the fibres a resemblance to cotton.

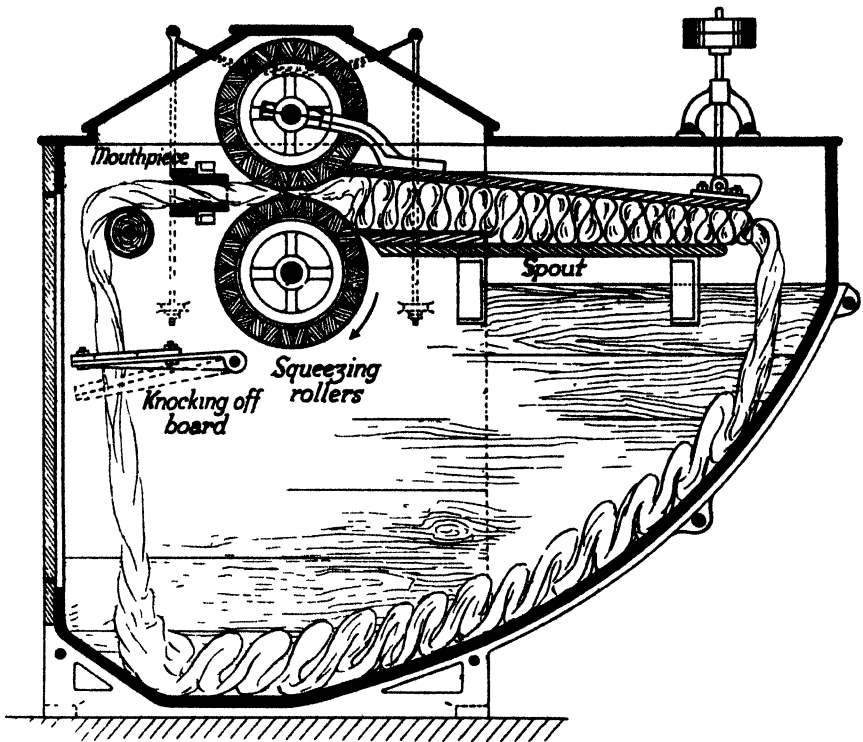


FIG. 6—Ordinary Rotary Milling Machine
NOTE—Spout shown is extra long.

Fig. 6 shows an ordinary milling machine with names of the principal parts. It has two main frames lined with pine boards and the bottom is curved to enable the cloth to slide easily to the front without ravelling.

The cloth passes between two squeezing rollers shod with oak cogs driven radially into mortice holes. They fit close together, and the grain being radial, they present a hard-wearing and gripping face to the cloth.

In sawing the cogs from the log, care is taken to get the natural "rays" of the wood approximately lengthwise with their faces, so as to avoid pieces breaking away and nipping the cloth.

In front of the rollers there is a mouthpiece which is frequently made of earthenware. It guides the piece into the rollers. The spout, in which most of the fulling occurs, is made of oak boards. The lid is attached to a casting hinged to the shaft of the top roller, which being like a "skip-jack," is called by that name. The lid is weighted to vary the amount of fulling, and it and the bottom of the spout next to the rollers are shod with brass plates.

Driving of Rollers

It used to be the practice to gear the two rollers together with wheels having long involute teeth, to remain in mesh when the cloth forced up the top roller. The vertical movement was limited, and the rollers had always to be of the correct diameter to suit the gear wheels.

It is now usual to fit pulleys on the shafts of the rollers, sometimes at both ends, and to connect them by ropes or belts which pass over jockey pulleys, as shown in Fig. 7. This method is quieter than gear wheels, and permits considerable vertical movement of the top roller. Sometimes Hans Renolds chains are used along with a jockey pulley.

Milling machines run at about 60 revs. per minute, and if the rollers are 20 inches in diameter, the cloth passes through at about 300 feet per minute, or $3\frac{1}{2}$ miles per hour. Experience has shown that this is a satisfactory speed, and that with a full load of cloth the correct temperature can be maintained. This is usually just below 45°C .

Quick and automatic stopping of the machine is an important factor, because if a knot or ravel were to get to the rollers and not go through, the piece would be damaged. For this reason a knocking-off board is used, which on being raised stops the machine.

Mill-Riggs

The principal difficulty with the milling machine, which differentiates it from the fulling stock, is that creases or mill-riggs are liable to form, owing to the folds in the cloth remaining in the same position. The milners have to watch for these.

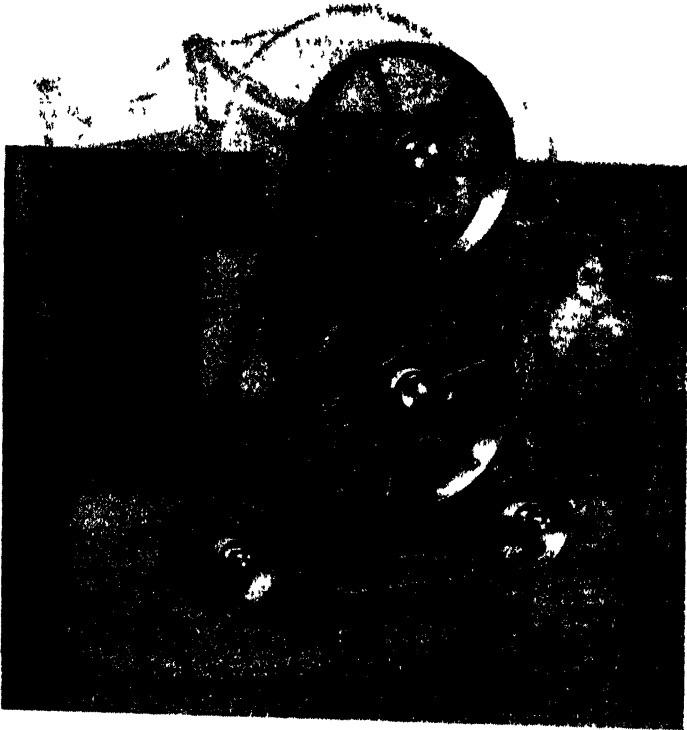


FIG 7—Flexible drive for top roller of Milling Machine (Mitchell & Sons).
NOTE—Two jockey pulleys give a belt wrap of about two-third's circumference. The jockey on the left falls by its own weight and keeps the belt taut.

One way is to rearrange or cross-draft the bights or drafts. For this purpose the knocking-off board is fitted with bars that are easily removable.

A hinged brass casting, with fingers to divide the bights, is convenient, as the milner has merely to remove a bolt and allow the casting to swing down, then he rearranges the cloth quickly and replaces the bolt.

Sometimes the selvages of the piece are sewn together to make it into a long tube like a length of knitted woollen fabric. The enclosed air then balloons out the piece, thus helping to change the folds.

Some years ago Mr H Roberts invented a rotary draft board which automatically changes the positions of the drafts and tends to keep them about the same length. It consists of a metal disc in which there are three or four round holes for the drafts. The disc is on the knocking-off board and rotates in a ball-race in either direction very easily. Fig 8 shows two such discs with three drafts in each.

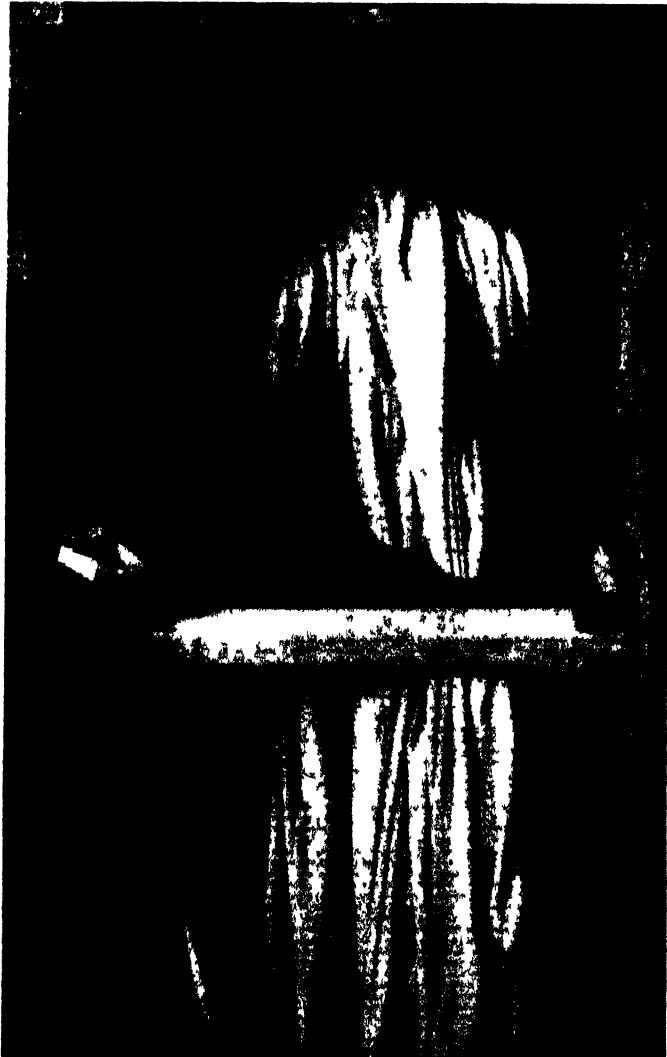


FIG 8—Roberts' rotary discs for Milling Machine
NOTE— Three round draft holes in each disc

Another method, which has been used in some Hemmer machines, is to rotate the disc forcibly, first in one direction and then in the other, thus making the bights or drafts take up new positions. The disc is driven by a small belt from the main shaft, and a gear box with throw-over motion, causes it to rotate for a given time in each direction.

Both these devices have round holes for the cloth to pass through, whereas ordinary knocking-off boards have square or rectangular holes, and these latter check the tendency of the piece to roll.

Stop-Motions

A common method of driving is by means of a belt that is moved by a fork onto a fast or loose pulley, according as to whether the machine is running or standing. The fork has attached to it a heavy weight, which is held out of action when the machine is running. Should a knot or ravel raise the knocking-off board the weight is released, the belt moved onto the loose pulley, and the machine stops.

It is usually 5 inches wide, and as the movement is done in about half a revolution of the pulley, that means the piece travels nearly 2 feet before the belt has completely moved across. In cases of a double machine or where more power is required, two belts and two fast and loose pulleys are used. This enables the belts to get across from one to the other quick enough to prevent damage to the piece.

In order to get quicker action, Richard Kilburn, about 70 years ago, adopted the pin or dog clutch mechanism. I believe it was first used on a machine at Wade's mill, in Wakefield. The movable part of the clutch has two pins which pass through holes in a casting keyed to the shaft. Whilst the machine is standing the pins are drawn back so that the pulley can rotate freely. To start the machine the pins must engage with the pulley.

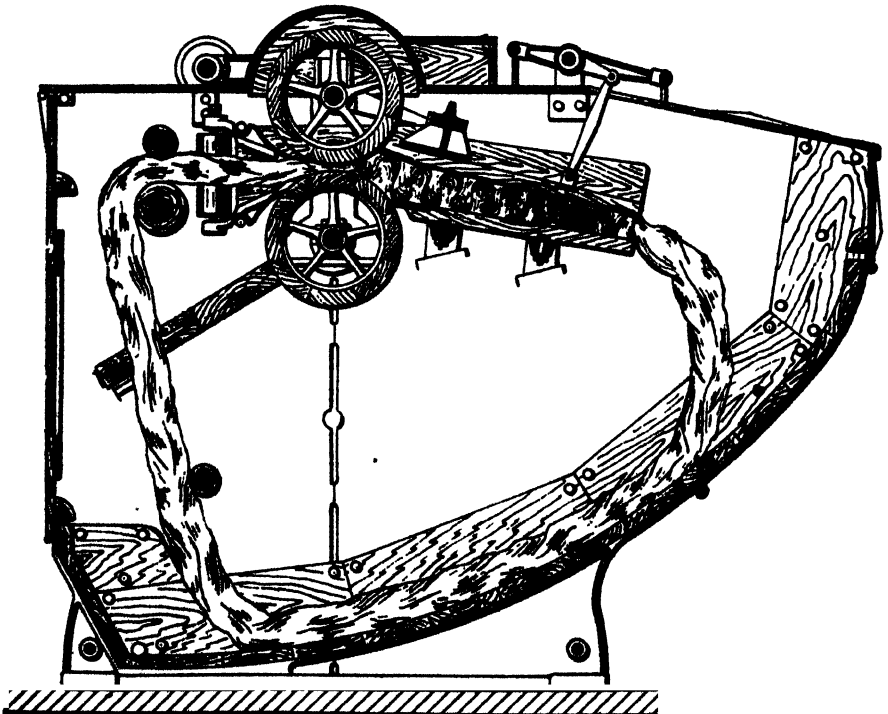


FIG. 9A

When the board is lowered it causes the bell crank lever to push forward the movable part of the clutch, and the pins engage with the hardened heads of bolts that clamp friction straps on the boss of a pulley. The clamping is sufficiently tight to enable the straps to give slightly when the machine starts.

Some firms use a circular clutch with a Ferodo lining, that is even quicker in action than the pin mechanism and for large machines, taking more than 6 h.p., this is the best arrangement.

Front Roller Stop-Motion

Hemmer machines are fitted with the automatic device in the front roller. When the machine is running normally, the roller rotates with the cloth, but if a knot occurs to stop the cloth the roller also stops moving.

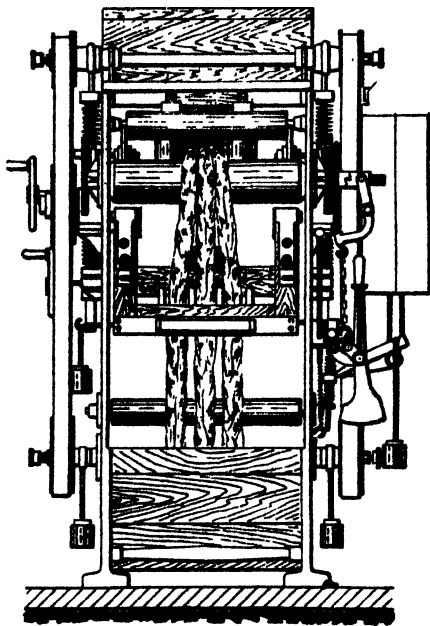


FIG. 9B

FIGS. 9A and 9B—German type of Milling Machine. It runs at 130 r.p.m. and requires 5 h.p.

NOTE.—Note automatic stop motion with claw on shaft of front roller (9B) and adjustable vertical rollers at the throat. The top roller has a flexible belt on each side.

On a sliding key on the shaft there is a small clutch having claw teeth which engage with other teeth on the boss of a rope pulley. The pulley is not keyed to the shaft, and it is driven from the main shaft, and so long as its speed synchronises with the speed of the front roller the claw teeth remain in engagement.

Should the front roller stop rotating, then as the rope pulley goes on, the inclined surfaces of the claws disengage and the clutch is pushed aside on its keyway. This sideways movement causes a lever to be tilted, which releases the weight, thus allowing the bell fork to move the belt from the fast to the loose pulley. Fig. 9 shows a Continental milling machine fitted with the automatic mechanism above described, and the claw of the clutch is indicated on it.

In a later design the loose pulley is replaced by a flywheel which, when the front roller stops, continues to revolve by its momentum. This again pushes the claw clutch sideways, and the machine stops directly there is relative movement between the two.

For large machines this appears to be a better and more sensitive arrangement than the usual knocking-off device. As machines become larger and more powerful and faster

running, the older millwright methods will have to give place to others of better engineering conception.

Double Machines

Double or tandem machines are occasionally made. Some by Whiteley's had the front rollers like those of an ordinary milling machine with flanges on the bottom roller, and the back pair of rollers 10 in. wide without flanges. The machine had two pairs of fast and loose pulleys, the reason being that a belt wider than 5 inches takes longer to move from the fast to the loose pulley, and the cloth may be damaged. Generally speaking, machines taking more than 5 h.p. should have double pulleys and two belts or be electrically driven.

As a matter of fact, the proper way to drive machines to-day is by electric motors directly mounted on them, and using as little intermediate gearing as possible, also to use a powerful modern circular clutch. The old methods of belting and long lineshafts are out of date.

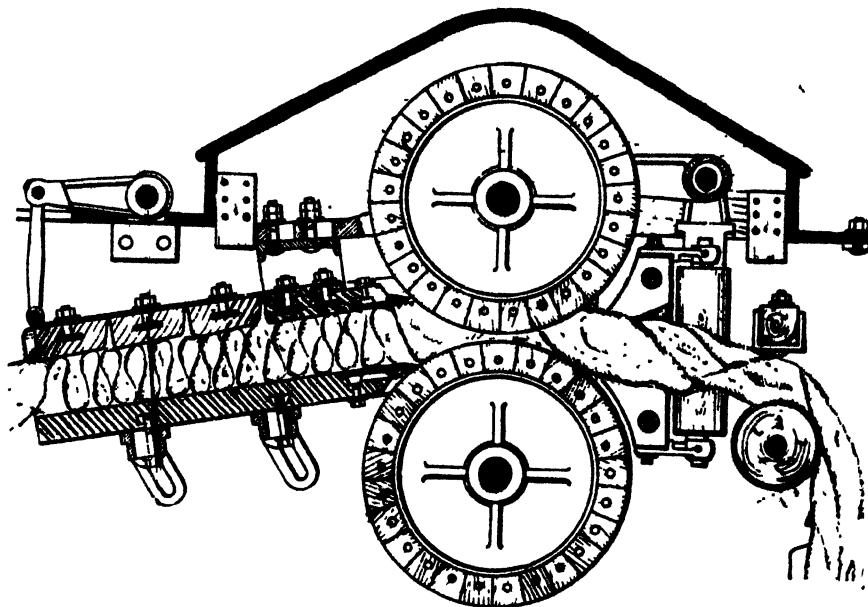


FIG. 10—Spout of Hemmer Machine with sectionalised lid.

NOTE—Adjustable vertical rollers between front or dicky rollers and main rollers.

Many attempts have been made to increase kneading action in the spout, one being to make the lid in sections as shown in Fig. 10. It will be noted that the lower roller has no flanges, and there are vertical rollers in the throat. About 30 years ago there was quite a craze for fitting so-called jumping rollers in the spout. There were three at the top and five at the bottom, and to increase the kneading they were corrugated. They certainly did increase fulling, but it was mainly a surface effect and had a tendency to make "flocks"

Partly arising out of this experience, the Kilburn firm is now fitting the bottom of the spout with six corrugated rollers. These are rotated in the *opposite* direction to that of the cloth; the effect is to pile up the cloth in the spout, which is consequently made about double the depth.

Pressure on Rollers

In the so-called German method of milling, rollers about 10 in. wide have their surfaces turned concave and convex. The curves cause a certain amount of sideway motion, and the differences in peripheral speeds at different parts of the surface set up a certain amount of friction that is claimed to assist the milling action.

As there are no flanges to the bottom roller it is important to guide the cloth correctly, and for this it is usual to fit a pair of short vertical rollers in front of the main rollers, or alternatively a pair of metal cheeks. The space between these is adjustable by a handwheel and screws, and generally a gauge is provided to indicate the adjustment. Milners take advantage of the restricted opening in the throat of the machine to retard the passage of the cloth to obtain longer pieces.

That pressure of the rollers has an important effect on fulling is shown by the following. During the war, Watkinson's Ltd., of Helenforth, finding that the fulling of khaki cloth took eight hours, and desiring to reduce the time, asked Whiteley's to alter the machine. They fitted the top rollers with stronger springs to give a pressure of about 400 lb., and reduced the time from 8 to $5\frac{1}{2}$ hours, but the power went up in about the same proportion, namely, from 6 h.p. to 9 h.p.

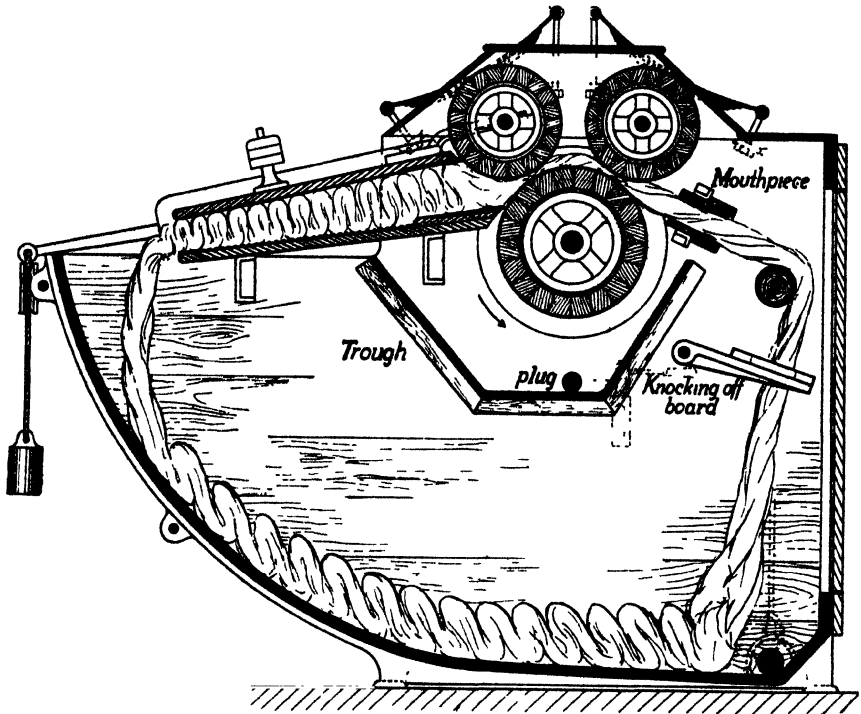


FIG 11--Kilburn combined scouring, milling, and washing machine

NOTE -Two top rollers; trough for scouring liquor, and spout with weighted movable sides in addition to weighted lid.

An example of the reverse effect is that of a machine made by Mitchell's for scouring the open, loosely woven fabrics of the Shetlands. It was desired to reduce fulling action during scouring, and so the top roller of greenheart, 2 ft. 3 in. in diameter and 5 ft. long, was suspended on levers and springs. The pressures on the fabrics could thus be ranged down to a few pounds per square inch, and fulling during scouring was prevented.

Combined Machines

When the processes of scouring, milling, and washing-off are done in three separate machines, a good deal of time is occupied in moving the pieces about, and in sewing the ends. This time is relatively great, for goods such as serges, worsteds and flannels, which do not need much fulling. In order to meet these conditions, the Kilburn combined machine was placed on the market in the early eighties, and I happened to be in at its birth by helping to make the patterns and erect the first machines.

As will be seen from Fig. 11, there are two top rollers running on a larger one which has flanges. Below is a trough for catching scouring liquor and water. The spout is special in that it has movable sides which are weighted, as well as the lid. The machine became a standard design for cloth that did not require

much fulling, and when knitted woollen fabrics began to be made in tubes up to 100 yards in length, it was quickly adopted for that trade.

The procedure in Leicestershire is to mill knitted fabric of good botany wool for $\frac{3}{4}$ hour; medium quality fabric for one hour; and low quality for two hours. Washing-off takes only about three minutes, because a great amount of water is used. Pieces 50 yards long are run in two drafts, and 100 yards length in four. About $1\frac{1}{2}$ lb. of soap is used for each 25 lb. weight of fabric.

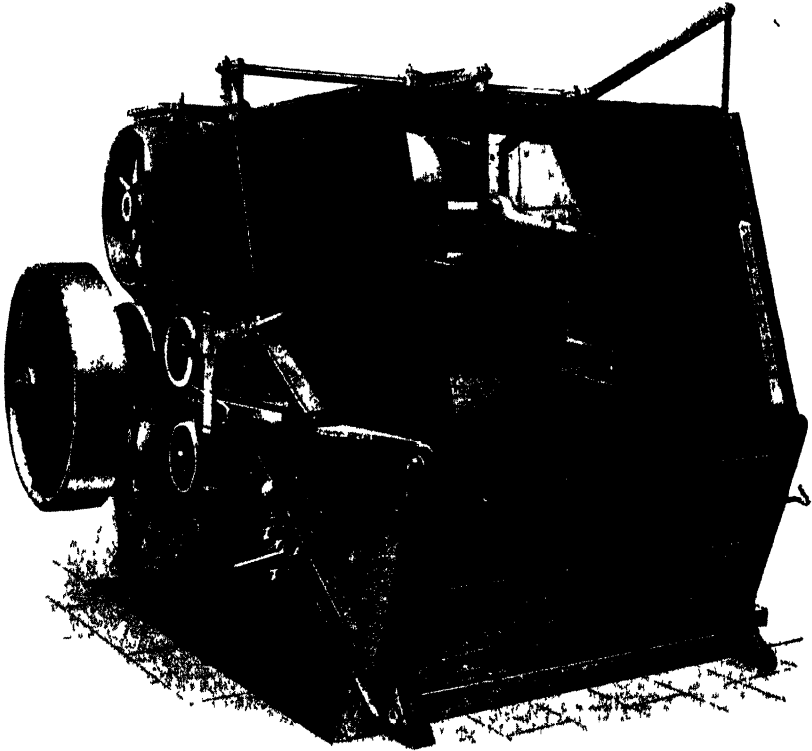


FIG. 12 - "Mitchell" combined scouring, milling, and washing machine
NOTE - Ample width and depth, corrugated spout and flexible drive for top roller

Mitchell's make the combined machine shown in Fig. 12, which has a large amount of room for scouring liquor and for lather. It has extra wide rollers without flanges, and the spout has longitudinal corrugations to press the cloth against the sides. The spout is placed at the front of the machine, where the milner can readily watch the pieces coming through.

The Head Milner of Joshua Wilson & Sons Ltd., informs me that worsteds take about $1\frac{1}{2}$ hours to scour and mill in Mitchell machines, and about 20 minutes to remove all soap. At another mill the times are $\frac{3}{4}$ hour for scouring, $\frac{1}{4}$ hour for drying, $\frac{1}{2}$ hour each for mulling and washing.

Felts for Paper Making

Machines for making paper use three kinds of felts, generally of the woven variety, and of course endless. One size is 25 feet wide and 75 feet long, but some are made nearly three times as large. There are looms in Bury which weave a 40-feet width.

Formerly the felts were fulled in extra wide crank-driven stocks, but the modern method is to use very large milling machines, as these reduce the time to about one-third, and give a more even finish.

As the felts are endless, they have to be placed into the machine from the side, and this involves removing part of the casting, one bearing of the lower roller, and the whole top roller. One side of the trough or spout has also to be lowered.

A Whiteley machine to mill an endless woven felt, weighing 10 cwt., has rollers of 33 in. diameter and 24 in. width, the machine being 14 feet long and 5 feet wide. The outboard bearing of the bottom roller is carried by a heavy bracket extending from the side of the machine.

The Hemmer firm has been successful with these large machines. One in the factory of Porritt Spencer Co. Ltd. measures 8 metres long, 4 metres high, and has main rollers $1\frac{1}{2}$ metres in diameter and 80 centimetres wide. It will take a load of 2,000 kilograms, or, say, 2 tons. The side castings are solid, with wood lining only where the felt runs.

For soap milling of felts it is usual to cover the metal with a special paint, but for acid milling the exposed metal is lined with lead. This was done with Hemmer machines supplied to Mitchell & Co. Ltd., of Waterford, for acid milling of real endless felts.

Large American Machines

Hunter machines are of two sizes, the particulars of which are as follows—

Size	MACHINE			PULLEY		Approx. Horse-power	Capacity of Cloth lb.	Number of Strings	Revs. per Min.
	Length	Height	Width inside	Dia-meter	Width				
No. 25	9' 7"	8' 9"	50"	30"	10 $\frac{1}{2}$ "	20	500	6 to 10	120
No. 30	10' 4"	9' 8"	60"	36 $\frac{1}{2}$ "	12 $\frac{1}{2}$ "	30	1,000	8 to 12	120

The machine is entirely iron clad, even the door being lined with galvanised iron. The drive is through a large circular clutch from an electric motor mounted on the side. The lining is of cyprus wood boards $1\frac{1}{2}$ in. thick, and the bottom is $1\frac{3}{8}$ in. The spout or "crimping box" is of hard wood, its sides being supported by castings to prevent warping.

The bearings are of the roller type, arranged to prevent oil seepage into the machine and the lubrication in them lasts six months. The springs of the top roller have a gauge to show the pressure and the metal sides of the throat have screw adjustment and a gauge to show the setting. It is thus possible to duplicate fulling results by keeping records of the same settings.

The following are some productions obtained by these machines compared with ordinary wooden milling machines. A No. 25 type in a Massachusetts factory working on 18 oz. woollens, 56 in. wide and 50 yards long, turned out six pieces in $2\frac{1}{2}$ hours as against two pieces in six hours by the old mill; an increase of about 500 per cent.

A No. 30 machine in a Connecticut factory working on light weight 14 oz. top coatings to finish 56 in. wide and 60 yards long, fulled ten pieces at a time, and did this six times in a day of ten hours. It was the output of 60 looms. Another machine in a Vermont mill, working on 23 oz. cotton warp top coatings, 36 in. in the grey to finish 30 in., increased the production 428% over standard wooden mills.

PART III—NEW SUGGESTIONS

Rust Prevention

It is now recognised that an essential factor of fulling is the change that takes place inside the fibres, which means that the fulling action begins at the root, which being open is vulnerable to chemical action. Naturally by increasing the number of roots in a given area, that is to say, having shorter fibres, the fulling action increases. It is also helped by using acid instead of soap.

In any case it is evident that chemical action has to be considered in the design of the fulling machines, and it is likely that a trend in future will be towards making machine-parts proof against chemicals. That brings in the question of what metals to use, or if linings are put on metals, whether they are to be lead, rubber, or other substances.

The most effective way of making iron rustless is, of course, to alloy it whilst molten with up to 12% of chromium. On account of the cost of this metal, difficulties of manufacture, and the royalties paid for patent rights, chrome steel is expensive. However, as more of it is used, and monopolies expire, prices must come down.

There are a number of methods of coating iron surfaces to prevent access of oxygen or rusting, e.g. painting, galvanising, electro-plating, and enamelling, and all have their particular uses. The most interesting, however, from the point of view of fulling machinery, is the coating of iron with magnetic oxide of iron. It is known as the "Trico" process and done by the Rustless Iron Co. Ltd. It started nearly half a century ago from experiments by Professor Barff, of Oxford, and Mr. Bower, a gas engineer of St. Neot's.

The oxide clings to the iron as if it were an actual part, and is about $\frac{1}{8}$ th in. thick. It withstands corrosion of the atmosphere and hot water, but does not effectively resist acids.

Changes in Design

The design of fulling stocks remained practically static for some hundred years, and for nearly half a century the rotary milling machine has remained the same. This is due partly to millners and millwrights preferring old methods. Lack of change is more noticeable, because all other textile machines, e.g. spinning wheels, carding engines, looms, etc. have altered considerably. It is partly due to the design and the making of such machinery being in the hands of engineers.

In most cloth mills the departments concerned with spinning and weaving are equipped with efficient machinery, and care is taken in the handling of wool and pieces. When, however, the pieces go to the groundfloor place, often called "t'millin' oil," they are often dragged about slimy stone floors and sometimes go through machines that have been so much repaired as to give the impression of being "tied up with band."

Along with mass production methods and speeding up, there must come into the finishing end of the business younger men with better technological training, and those who take charge will desire larger and more "engineeringly designed" machines than are now in use.

Driving of Machines

The finishing departments of many cloth mills in this country were laid out before electric driving came into vogue; consequently they have long lineshafts, dangerous flapping belts, and noisy gearing. It is high time old-fashioned ways of applying power to fulling, dyeing and other forms of finishing machines, were displaced.

The ideal method of driving is by means of electric motors, and preferably by a motor on each machine. Speeds of the motors should be kept low in order to minimise the amount of reduction gearing. In any case this gearing should have cut teeth and run in an enclosed oil bath. Bearings should be of the automatic ring oiling or, preferably, the ball or roller type.

At one time switch gear was somewhat fragile, but to-day practically all makers supply so-called "foolproof" designs. One great advantage of electric switch gear is that it is so easy to arrange for automatic stopping and starting. Much switching is done by what is known as "push-button control". In the case of a milling machine the rising of the knocking-off board or slowing of the top roller can trip the switch, and cutting off the current immediately applies an electro magnetic brake.

Practical Research

Some milners believe that fulling in the spout of a rotary milling machine can be divided into, first, the action of the sides on weft threads to reduce width, and second, the action of the lid on the warps to reduce length. Several years ago, I suggested that an investigation of this belief might be made by fitting the sides of a spout with glass windows and small electric lamps, to observe foldings and movements of the cloth with varying conditions of pressure, speed, etc. The spout could also be fitted with electric resistant heaters of the "matt type," so that temperatures could be varied with great nicety. There might also be a cooling device.

Electricity enters intimately into so many industrial operations that it may be found to be a factor in fulling. There is much friction between the folds of the cloth and between the cloth and the sides of the spout. The fact that well-seasoned oak is a good insulator gives point to the suggestion. It might be feasible to pass electric current into the cloth from plates on the spout sides.

Creases or mill-rigs, started in a rotary milling machine, can be prevented from extending by running the piece in a fulling stock, in order to obviate the moving of the piece from one machine to the other and back again. Some years ago an attempt was made to apply a crank stock to a milling machine. There is one in the Textile Department of the University of Leeds. It was not successful, partly because the cloth could not remain under the feet long enough.

I think it is possible to utilise the open space in the lower part of a milling machine with a row of beaters something like those of "Tom tom" machines used for knitted woollen goods. The beaters would be weighted and worked by cams on a spindle below the main shaft, a clutch being provided to throw the beaters in and out of action.

In order to provide plenty of cloth for the beaters to work upon, I suggest having an open box in the bottom for it to accumulate in. Also the spout might be made extra large and have a lever to lift the lid at regular intervals, so as to pass a quantity of cloth into the box below. Then whilst one lot of cloth was being acted upon, another lot would be accumulating in the spout, ready for the next release on lifting the lid.

It would be easy to apply beaters to existing machines, and doubtless from experience with them, other developments would follow as is always the way with new experiments. It is little use talking about what may be done; the thing to do is try and try again.

NOTES AND NOTICES

Lancashire Section Announcements

At last meeting of the Committee of the Lancashire Section of the Institute, Mr. T. E. Mitchell, F.T.I., of Rochdale, was re-elected Chairman. Arrangements for the forthcoming session of meetings were considered and it was agreed to promote about half-a-dozen meetings for Papers or Lectures—three or four at Headquarters, one at Bolton, and one at Preston. Attention was drawn to the fact that no social assembly had been organised in recent years and it was unanimously decided that a dinner dance should take place on a Saturday evening, preferably during December. It was afterwards found, however, that the only available date, at the place selected, Restaurant of Manchester Ltd., Exchange Buildings, is that of the 13th January next and this date has been accepted. It is hoped that Members of the Section will bear the date in mind and invite friends to participate.

Fabrics for Industrial Purposes

Following up previous efforts in regard to the use of textiles in industry, the first and second regular meetings of the session of the Lancashire Section are of special interest. The first event is to take the form of a meeting to be held conjointly with the North-West Section of the Institution of Rubber Industry, at which contributions on the subject of "Cotton Fabrics for the Rubber Industry" will be provided by Mr. T. Fletcher Chadwick, F.T.I. and Mr. W. H. Reece, B.Sc., A.I.C., A.I.R.I.(Sc.). The meeting is fixed to take place at the Manchester College of Technology on the evening of the 16th October. On the 15th November, 7.30 p.m., a Paper on "Fabrics for the Boot and Shoe Industry" is to be given by Mr. W. Wilkinson, O.B.E., F.T.I., Head of Blackburn Technical College. In regard to this Paper, Mr. Harold Salt, H.M.I. has co-operated in regard to specimens and it is hoped that Mr. Salt may be able to attend. Further announcements will be made in due course as to other meetings contemplated by the Lancashire Section Committee.

The Midlands Section

The Committee of this Section of the Institute is to be congratulated on its lead in early publication of a completed programme of meetings. Mr. T. A. Purt (Leicester), who has succeeded Mr. J. Chamberlain in the position of Hon. Secretary, is maintaining the reputation of the Section in the matter of early preparation of the programme. The events announced are as follows—

19th October—Visit to Dunlop Rubber Company's Works at Fort Dunlop, at 2 p.m. (Address by R. Truesdale, A.T.I.).

16th November, 7.30 p.m.—Lecture on "Modern Methods of Underwear Manufacture," by A. Wilfred Swann, at Leicester College of Art and Technology.

13th December—Visit to Works of Messrs. G. H. Heath & Co. Ltd., at Sandbach. (Address on Silk Throwing).

There are meetings in each of the first three months of next year—At Nottingham on the evening of 18th January, "Sewing Cottons and their Uses," by A. Stoppard, of Messrs. J. W. Williams Ltd.; at Derby on the evening of 14th February, "Textiles Purchased by British Railways, and their Applications," by William Pritchard, of L.M. & S. Textile Research Department. Finally, on the afternoon of 21st March, there is to be a visit to the Works of Messrs. Brintons Ltd., carpet manufacturers, at Kidderminster.

Textile Institute Diplomas

Elections to Fellowship and Associateship have been completed as follows since the appearance of the previous list (July issue of this *Journal*)—

FELLOWSHIP

CLARK, Cyril Oldtree (Bradford)

ASSOCIATESHIP

GARNER, Walter (Bradford).

Institute Membership

At the September meeting of the Council, the following were elected to Membership of the Institute—*Ordinary*, H. I. Hayashi, c/o Nippon Keori Kaisha Nagoya Works, Iwatsukacho, Nagoyashi, Japan (Chief Engineer); D. W. Law, Budge Budge Jute Mills, Budge Budge, Bengal, India (Mechanical Assistant); P. Pal, 14 Duncan Road, Longsight, Manchester 13 (Student).

Junior—N. B. Carrier, 405 Alfreton Road, Nottingham (Sewing Cotton Clerk); W. A. Dutton, 50 Springfield Gardens, Ilkeston, Derbyshire (Senior Assistant, Yarn and Testing Bureau); J. R. Greenwood, 439 Keighley Road, Morton, near Bingley (Student); W. Hodgson, 18 East Parade, Baildon, near Shipley (Drawing and Spinning Trainee); J. Senior, 3 Westfield Terrace, Baildon (Wool Sorter).

Life Membership—Fred Briggs, 29 Shear Brow, Blackburn.

THE JOURNAL OF THE TEXTILE INSTITUTE

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OCTOBER 1933

No. 10

PROCEEDINGS Irish Section

*Meeting at the Municipal College of Technology, Belfast, on Thursday,
26th January 1933; Mr. F. H. Whysall in the chair.*

ELECTRICITY AND ITS APPLICATION IN TEXTILE WORKS WITH SPECIAL REFERENCE TO THE LINEN INDUSTRY*

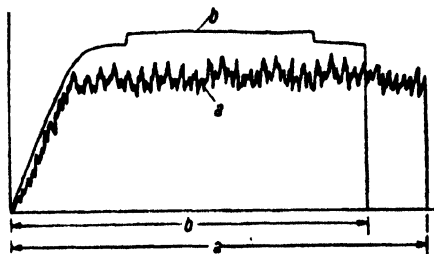
An interesting paper on "Electricity and its Application in Textile Works, with special reference to the Linen Industry," was recently read by Mr. Friend, Member, before the Irish Section of the Institute in Belfast.

After pointing out that the applications of electricity to this industry were so large in number and varied in character that he must by reason of the time at his disposal confine himself to dealing with the more important examples, he stated that the individual electric drive is the best system to install where steady running is desired. He said "The actual speed of the machine when driven by an individual electric motor is always equal to the nominal speed. As is generally known, the long belts necessary with lineshaft drive are continually stretching, so that the slip increases as time goes on, resulting in the machine speed being slower than calculated. The speed of line-shafting is also a varying one, which makes it necessary to take a mean speed when calculating production. Fluctuations in the speed of the shafting mean instability of the whole driving system and impair the smooth operation of the machine. The elimination of all extraneous vibration by the individual drive enables the speed of the machine to be raised by a few per cent. without detriment. A comparison between the speed of lineshaft driven and individually-driven machines is shown in Fig. 1. Spinning and doubling machinery, in particular, require variable-speed drives and the individual motor makes



a = Line-shaft Drive
b = Individual Electric Drive

Fig 1 Speed Curves for Lineshaft and Individual Electric Drives



a = Line-shaft Drive
b = Individual Electric Drive

Fig 2—Speed Curves on a Flyer Spinning Frame with Lineshaft Drive and Individual Drive by 3-phase Commutator Motor.

* This report provides a fuller reference to a meeting which has already been briefly recorded—see April issue, page P63, 1933.

it possible to adjust the speed as required at the beginning, middle, and end of the set. Fig. 2 is a corresponding speed diagram for a flyer spinning frame. The individual drive shows an advantage over the group drive when a mill is running intermittently and Fig. 3 indicates this advantage. Figs. 4 (a) and 4 (b) give a comparison of a loom driven individually by a gear drive with an exactly similar loom driven on the group drive principle from a lineshaft. In the first case speed oscillations are uniform and in the second considerable fluctuations occur. A more evenly constructed cloth is thus produced by the former."

The lecturer then pointed out that the use, to-day, of direct current motors is declining and their place being taken by alternating current motors. These are generally of the three-phase alternating current type, the supply being, usually, approximately 400 volts, 3-phase, 50 cycles. Two main types exist, the "slip-ring" and the "squirrel-cage" motors. The lecturer gave a brief account of the characteristics and employment of these two types of individual motor. He emphasised that disappointment had been caused in the past by the wrong application of motors to the machines they were required to drive.

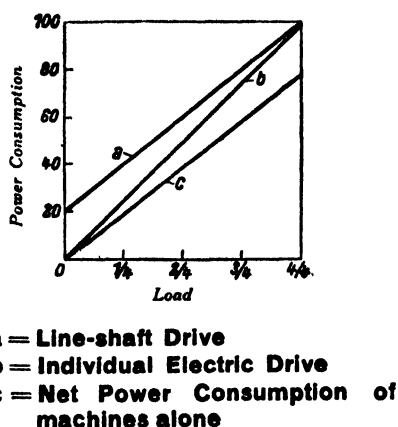


Fig. 3.—Power Consumption of intermittently-run machines with Lineshaft Drive and Individual Electric Drive, and net power consumption of machines alone.

In dealing with the mechanical feature of the motors, Mr. Friend said "Generally speaking, the type of enclosure advised and adopted for use in textile mills is the totally-enclosed machine, Fig. 5, whether it be of the slip-ring or squirrel-cage type. These totally-enclosed motors have no openings whatever and are specially suited to work in an atmosphere laden with dust or inflammable matter. Cooling is effected by ribs distributed around the stator casing and by the action of a fan. The fan is mounted outside the motor end-shield and protected by a cover, the air being blown by the fan in a horizontal direction along the motor frame, thus coming into intimate contact with the ribbed surface of the stator over its entire length. There is no necessity for an outer casing, and all danger of overheating such as may be caused by clogging of the air passages of double casing motors is eliminated. In cases where an even smaller overall size of motor is required for a given output a pipe-ventilated type of motor may be used, in which case fresh air is led to the intake side of the motor and the hot air exhausted from the motor either into the room or by means of ducts to the outer atmosphere."

He then went on briefly to describe the three-phase commutator motor, Fig. 6, which has found a considerable vogue on the Continent, but hitherto has made very little progress in this country. It is used where variation in speed is required and this is effectively accomplished by a simple rotary movement of the

brush gear, either by hand or automatically from the mechanism of the driven machine itself, *e.g.* the ring spinning frame. This can be carried out with little or no fall in the efficiency of the motor. It may be urged, however, that this desirable characteristic of simple, highly-efficient speed variation is offset by the higher initial cost of the motor and the corresponding ventilating air ducts, greater floor space required and probably higher maintenance costs compared with the simple squirrel-cage type of motor. The relative importance of these individual features can, of course, only correctly be assessed for each particular case.

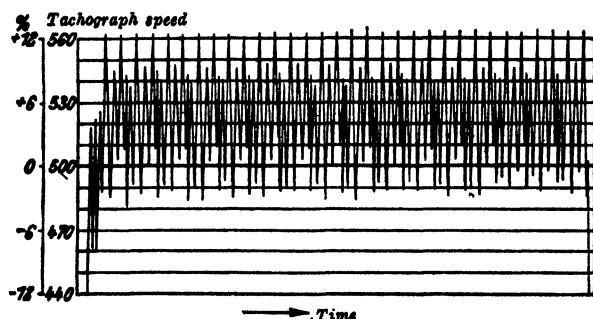


FIG. 4a—Speed Graph of Individual Gear Drive on a Loom.

Dealing with starting gear, Mr. Friend enumerated the types employed with slip-ring and with squirrel-cage motors. For textile machinery where steady speeds are absolutely necessary, he recommended the direct-on starter, Fig. 7, for the squirrel-cage motor rather than the star-delta starter. For use with loom motors, special loom switches are supplied which are, in effect, straight-on starters and are attached to the loom starting handle. Should a loom "bang-off," the switch is opened and the motor stops.

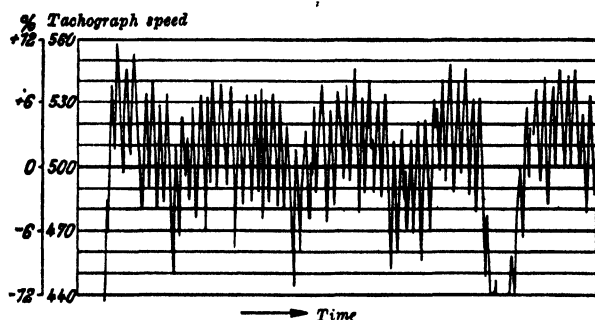


FIG. 4b—Speed Graph of a Lineshaft-driven Loom.

The various types of the transmission of power from the motor to the driven machine were then described and it was pointed out that wherever possible direct coupling should be employed, which, however, is only possible when the speed of the machine corresponds with one of the standard speeds for A.C. electric motors (other than the commutator type). It might be suggested that designers of textile machinery would do well by designing their machines to run at standard A.C. motor speeds, particularly as the periodicity of electricity has now been standardised at 50 cycles. "Where it is not possible to couple the motor directly,"

the lecturer continued, "then a form of transmission giving the highest efficiency has to be chosen. It should always be remembered when selecting motors that the higher the speed the lower the cost, as horse-power is a function of the speed." For example, a 10-h.p. motor running at 1,500 r.p.m. was smaller and therefore cheaper than one running at 1,000 r.p.m. Therefore, with an efficient type of transmission it was often found possible to use a high-speed motor taking advantage of a larger speed ratio. There were, said Mr. Friend, several forms of transmission in use to-day, and proceeded to outline the advantages and disadvantages of these.

Gear Drive (Fig. 8)—Here we had a positive type of drive transmitting power without slip and conserving space. The gear drive, however, was not proof against shocks; it was no noisier than a chain, but could not be used where the centres were extremely large; great care must be taken in erection and it was advisable that both motor and the driven machine or shaft should be mounted on one common bed. Particularly good bearing arrangements should be made, especially on overhung shafting.

Chain Drive (Fig. 9)—This type of drive was again a positive drive without slip, showing economy of space. It absorbed shocks when the chain centres were sufficiently long and was fairly silent. With this drive, however, care must be taken in erection and chains could not be used for extreme centre distances. It was necessary that the chain should be liberally oiled, which necessitates an oil-type chain case. The motor must be mounted on slide rails or have some means of adjustment to take up any chain slackness or stretch.

Belt Drive with Jockey Pulley (Fig. 5)—This type of drive absorbed any shocks; was silent; was not necessary to provide centre adjustment on the motor; and was easy of erection. There was no danger of belt breaking on overload and no lubrication was required. The objections to this type of drive were that it was not by any means a positive one; it generally required more room for accommodation and there was considerable wear and tear on the belts.

V-rope Drive (Fig. 10)—This form of drive, which was becoming popular, would withstand small shocks and often showed advantage in saving of space due to the short centres which might be used. It was noiseless and required no lubrication; it need not be put under tension, which avoided shaft and bearing stresses. Against this it should be noted that with the V-rope drive it was necessary to make arrangements for moving the motor to take up any stretch of the ropes. Wear and tear on the ropes was fairly high and as the ropes had a rubber base these must be protected from oil. Also, when one of the ropes breaks, the remaining ropes in the drive must be changed as it is only permissible to use ropes of equal length.

Motors with Self-contained Reduction Gearing (Fig. 11)—This form of drive, as the gear drive, was a positive one, there being no losses due to slip. It afforded great saving in space, and the driving shaft could be direct-coupled to the driven shaft, which meant simple erection. Small high-speed motors for driving slow running machines could be utilised. This drive was noiseless. Here again, however, the gears would not stand shocks, so that if these were likely to occur the general practice was to use flexible couplings.

The development of this latter type of drive, namely the motor with self-contained reduction gearing for the direct drive of slow speed machines, had met with wide approval, said Mr. Friend. The requirements occurring in practice necessitated special attention to this problem and in order to attain the end in view, entirely new avenues in gearing science had had to be explored. Based on the experience of the many hundreds of geared motors already in service, it could be stated that the geared motor was an important milestone in the development of the individual electric drive. It must be remembered that a reduction gear, often for a very considerable speed ratio, was required to be built together with an electric machine and that the overall dimensions of the gearing

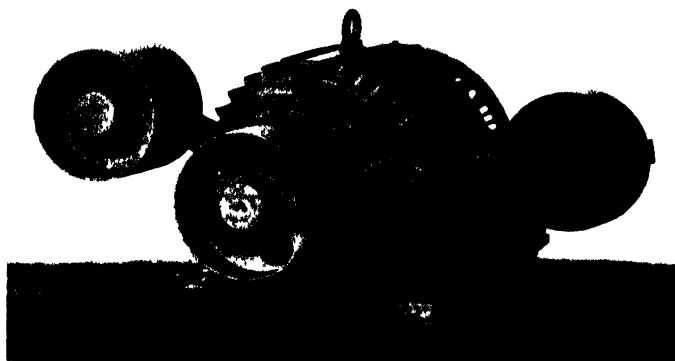


FIG. 5 Totally enclosed surface cooled Motor with built on Jockey Pulley

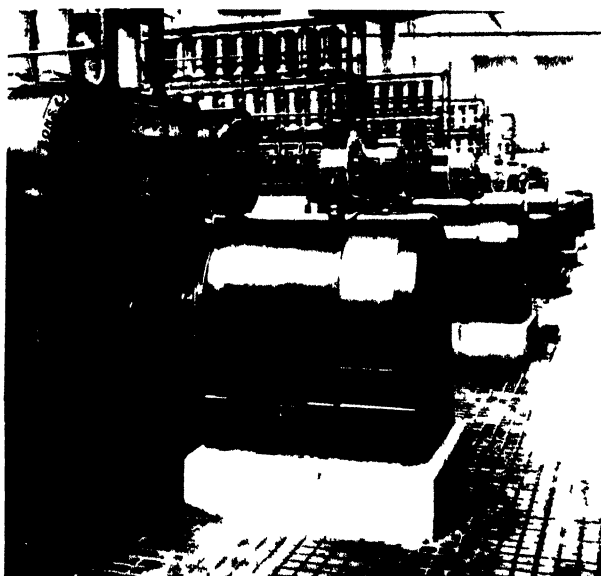


FIG. 6 Linen Spinning Frames driven by Variable Speed Motors



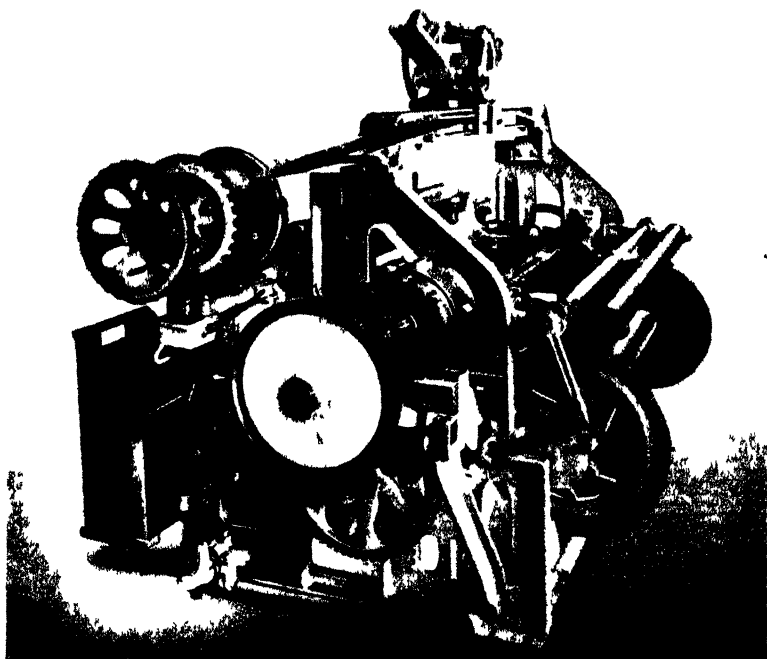


FIG. 8 Individually driven Loom (Gear Drive)

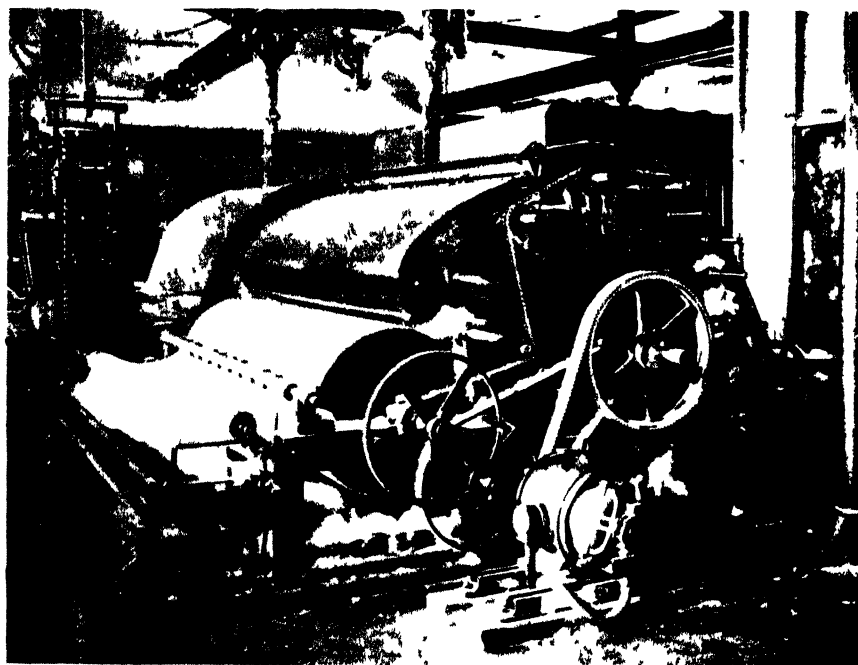


FIG. 9 Card driven through Inverted Tooth Chain

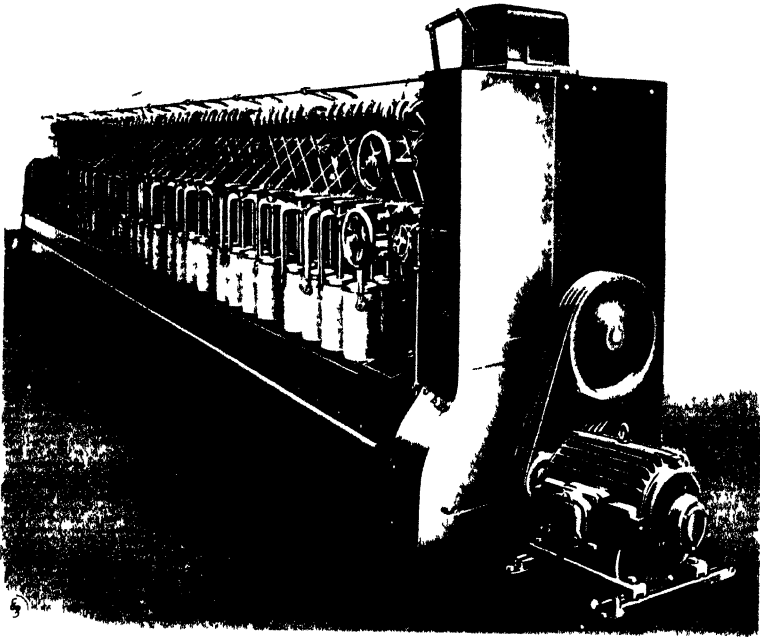
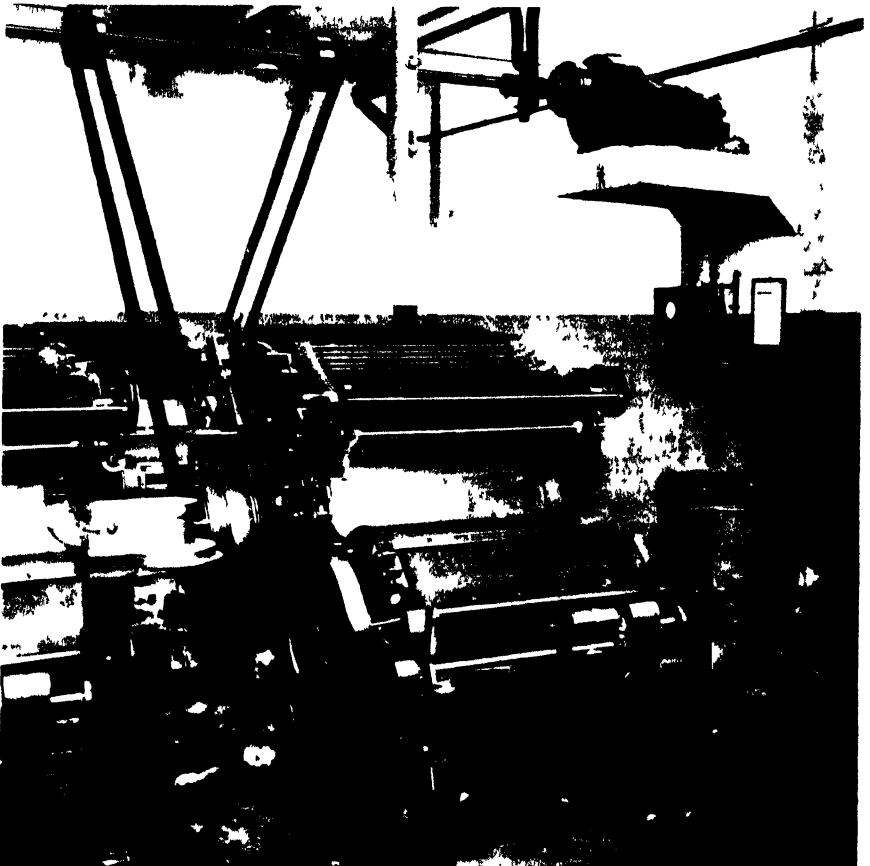


Fig 10 Spinning Frame driven through V Ropes



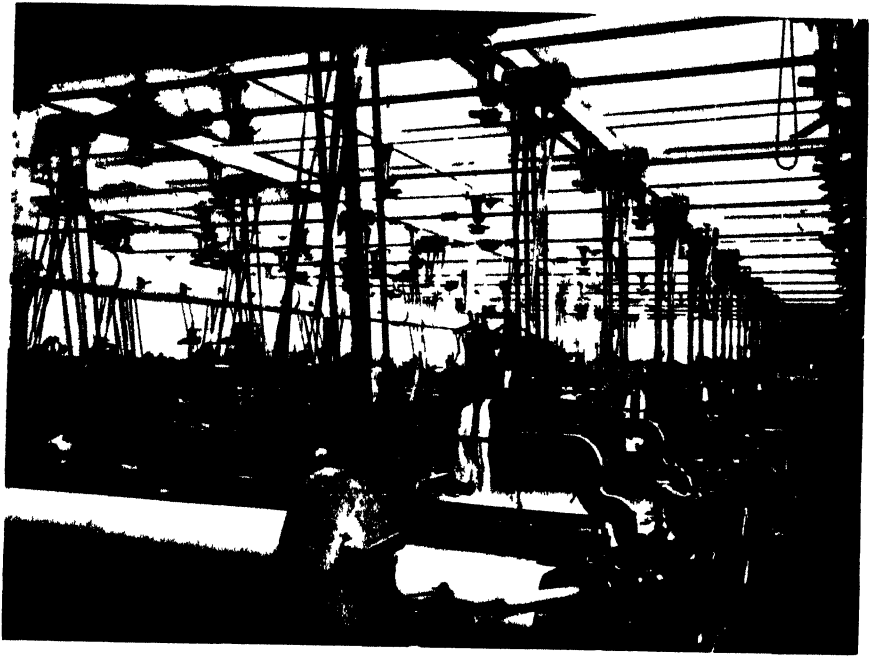


FIG. 12 Group driven Loom Shed before conversion to Individual Drive



FIG. 13 Individually driven Looms after conversion
(See Fig. 12)

should be, up to a fine limit, those of the motor if a compact design was to be secured. At the same time the geared motor must not be higher in price than a motor with separate reduction gearing, coupling, and the usual combined base-plate. For the larger types of geared motors, with outputs up to several hundreds of kilowatts, it was the practice to employ double helical wheels, since the main consideration in the design of these motors was the choice of a high quality gear having the lowest losses and maximum length of life combined with silent operation.

Mr. Friend then dealt in detail with the application of the individual motor to the various machines in the opening department, and also to the cards and roving frames, and described fully the method of driving ring spinning frames and mules which, as he truly remarked, are perhaps the most interesting drives from the electrical engineer's point of view. He continued, "Spinning frames require an exceptionally steady speed and in practically all cases production may be improved and increased by the use of a variable-speed motor. It is well known that the spinning of fibres may be carried out at a higher speed on larger cop diameters than on the smaller ones and, with the variable-speed commutator motor, is provided a spinning regulator, which regulator is driven from the heart and ratchet shafts and the motion then transmitted to the brush rocking and starting handle of the motor. By the use of specially-cut cams in this spinning regulator the desired rise and fall in speed is obtained. The type of drive just described is known as the individual variable-speed drive for spinning frames. For flyer spinning frames, however, the individual drive has been even further developed. Since the introduction of the individual electric spindle drive for flyer spinning frames about 20 years ago, it has been found possible to increase the production on these machines by about 40%. As a result of this, textile machinists have endeavoured to improve the construction of the spinning frame with mechanically driven spindles, so that the electric spindles have been acting as a pacemaker. The spinning frame with mechanical spindle drive has so far advanced to-day that with its low initial cost it is in many ways comparable with the individual electric spindle machine. However, it is not possible to take full advantage of the individual electric spindle drive, as the present design of the flyer spinning machine does not allow of especially high spindle speeds. Nevertheless the individual electric spindle machine has several particular advantages, the tin drum, bands or tapes and gearing are redundant, resulting in better transmission efficiency, lower power consumption, quieter running, less complicated arrangement and greater cleanliness."

"Where neither the individual spindle drive nor the variable-speed commutator motor drive is adopted for flyer spinning machines the totally-enclosed, surface-cooled squirrel-cage motor is used and two of these, each with a combined jockey pulley arrangement, may be placed inside the end frame of the machines, thereby making a particularly neat arrangement. The motors are started up by means of straight-on switches with push button control and the machine is started by lowering the jockey pulley on to the belt, thereby gradually taking up the load on the machine. In case it is found impossible to accommodate the two motors inside the end frame the motors may be turned around and placed in the alley-way."

"Other types of spinning frames may also be driven by a constant-speed motor and for this purpose the ordinary squirrel-cage motor is often employed. In this case the motor may be either direct-coupled to the tin drum shaft or driven through chains, gears or other means of transmission. When a form of transmission is used other than direct coupling, the motor may be placed on the floor or on top of the headstock, as is most convenient. The latter method is often applied to conserve space. When driving spinning frames by means of a constant speed motor, it is advisable to employ a straight-on switch used in conjunction with resistances to give a slow, soft start. Whilst on the subject of spinning, a few words

on the individual electric drive for mules may be interesting. Messrs. Siemens-Schuckert have patented a special type of mule motor, which motor, when used for driving cotton or wool mules, is direct-coupled to the mule countershaft or, in the case of condenser mules, mounted on an elevation of the front headstock. The motors used in either case are of the squirrel-cage type of special design so arranged electrically that a slip in speed of about 20% takes place at the instant the carriage starts to run out, thus ensuring an easy start of the carriage without jerks and fewer broken ends. The increase in production by adopting this form of drive ranges between 5% and 10%. The smooth running of individually-driven mules is apparent owing to the ease with which this motor overcomes the heavy pull at each outward run of the carriage. The acceleration of the carriage and spindles is greater, but at the same time smoother than when driven from line-shafting. Irregularities of the rim shaft speed, invariably met with in the case of group-driven mules, as a result of mutual interference, are completely eliminated by individual driving. This is reflected in improved spinning and a better quality of yarn. Further, for the individual drive of mules the motor may be mounted direct on to the headstock and drive through gears to the rimshaft, into which a magnetic coupling is introduced. This eliminates the use of belts entirely."

The driving of the various machines in the preparation and weaving departments was then described with special reference to the individual drive of looms, Figs. 12 and 13, which followed closely what has now come to be regarded as the best standard practice. Then followed reference to the employment of individual electric driving in bleaching, dyeing, finishing and print works. Owing to fluctuation in demand, and changes of fashion, rearrangement of the number and sequences of processes has frequently to be made. This resulted in temporary idleness for some machine and radical alteration of the conditions under which others had to be operated. The individual drive obviated loss of power in turning idle countershafts, and provided freedom of choice of situation for the various machines employed. The lecturer referred particularly to the driving of hydro-extractors, mangles and calenders, and cloth printing machines, giving advice in the choice of motors suitable to each machine.

The final portion of the lecture dealt with illumination in the mill, giving particulars of the quantities of light measured in foot-candles required by operatives for efficiently carrying out the various processes as well as particulars of the best types of fitting to employ.

The paper was illustrated by many interesting and instructive lantern slides, a few of which are reproduced.

London Section

Visit To Manchester

Promoted by the London Section Committee of the Institute, a visit to mills and warehouses in Manchester took place during September—20th to 22nd inclusive. The event was organised not only for the benefit of members of the Section but also of representatives of the textile distributive interests in London and the South. The Chairman of the Section Committee (Mr. J. Howard) kindly attended and was supported by Mr. W. H. Matthews (Board of Trade). In all, 18 persons took part in the visit and the following firms were represented—Army & Navy Co-operative Society Ltd. (3), John Lewis Partnership (3), Selfridge & Co. Ltd. (6), Perkin Bros. (Plymouth), W. G. Housley & Co. (Richmond). Miss Martin (London) was present as representative of the Linen Industry Research Association. On arrival at Manchester, the party were met by Mr. F. Nasmith, representing the Council of the Institute, and later were escorted to the warehouse of Messrs. Tootal, Broadhurst Lee Co. Ltd., where they were received by Mr. J. H. Lester.

Afterwards, the company attended at the Textile Institute Headquarters and partook of tea along with a number of members of the Council, the Chairman (Mr. Frank Wright) extending a hearty welcome to the visitors. On Thursday, the Jackson Street Mills of the Fine Cotton Spinners & Doublers' Association and the mills of Messrs. Richard Haworth & Co. at Salford were visited, the concluding item of the programme of the day being a drive to the municipal park at Wythen-shawe, where tea was served in the old hall. On the Friday morning, the company visited the showrooms of the Calico Printers' Association. After luncheon at the Institute by kind invitation of the Chairman of Council, the party proceeded to inspect the demonstration Department at the works of the Universal Winding Co. The Chairman of the Section (Mr. Howard) and also Mr. Matthews expressed the thanks of the Company to the Council, to Mr. Frank Wright, to Mr. Nasmith, and to all concerned in the effecting of arrangements.

NOTES AND NOTICES

Institute Examination—June 1933

The results of the Institute's Examination (Part II, General Textile Technology) were announced and approved at the September meeting of the Council. The Examination was held simultaneously, in June last, at Manchester, Glasgow, Leicester, Belfast, Bombay, and Calcutta. There were 32 candidates and 24, as named below, passed—

H. Beevers (Elland); A. Bibby (Derby); S. Binns (Rochdale); W. Breakell (Oldham); H. R. Brooksbank (Bradford); F. W. Fogg (Nottingham); Wm. Graham (Blackburn); H. Haigh (Bradford); T. Hodkin (London); F. Ibbetson (Bradford); J. R. Ickringill (Keighley); D. Laidlaw (Hawick); H. Laithwaite (Oldham); C. J. Lancashire (Leicester); F. B. Lindley (Paisley); Y. S. Mirza (Bombay, India); A. S. Moss (Elderslie, Renfrewshire); Wm. Pickup (Preston); F. C. Price (Heanor, Notts.); N. Rhodes (Oldham); T. Scholes (Hyde); E. F. Shroff (Dadar, India); W. H. Towle (Loughborough); Walter Walker (Bolton).

Two of the candidates (W. Breakell and N. Rhodes) also sat for, and passed, Part I (Auxiliary Subjects) of the Examination.

Manchester College of Technology

At the ceremony of presentation of the Associateship of the Manchester College of Technology, which took place at the College on the evening of Saturday 30th September, three Honorary Associateships were conferred upon Sir John Dewrance, Mr. John William Nasmith, and Mr. Frank Twyman. The selection of Mr. J. W. Nasmith was of particular interest to all concerned in the textile industry. In 1931, the Council of the Textile Institute marked their appreciation of the distinguished record of Mr. Nasmith by the award of the Honorary Fellowship of the Institute, an honour which is reserved for outstanding services to the textile industry. In presenting Mr. Nasmith, Mr. David Cardwell alluded to the recipient as an acknowledged master of the arts and mysteries of the textile machinist and a mechanical genius who had invented the Nasmith Comber which opened up a new era in the combing of short-stapled cottons. Mr. Cardwell added that in conferring the Honorary Associateship upon Mr. Nasmith, they were forging another link in a long chain of connection with the College. Mr. Nasmith's father was a teacher at the old Mechanics' Institute, whilst his son and his nephew (Mr. Frank Nasmith) were its distinguished alumni, and the fourth generation was represented among present students. In the course of the proceedings, the Principle of the College, Mr. B. Mouat Jones, gave some interesting particulars of the numbers of students and classes of the College. Many more students were

taking courses of four or five classes and fewer were taking single classes. In 1913-1914, there were 4,700 students and 1,287 classes, whereas in 1932-1933 there were 6,400 students and 2,051 classes. In 1914, 35 students gained the Associateship; in 1921 the corresponding number was 91; and on the present occasion 156 Associateships were awarded—38 in Mechanical Engineering, 28 Electrical Engineering, 5 Municipal Engineering, 18 Building, 36 Pure and Applied Chemistry, 15 Textile Chemistry, 15 Textile Industries, and 1 Industrial Administration.

Textile Institute Scholarship

Mr. Alan Ratcliffe, of Walkden, near Manchester, who has just recently completed a three years' Scholarship, awarded by the Institute in 1930, has secured an important post on the management side at the chief works of Messrs. Morton Sundour Fabrics Ltd., at Carlisle. Between 25 and 26 years of age, Mr. Ratcliffe's career in technical training has been attended with marked achievement. His scholarship period has embraced a two years' special course at Manchester College of Technology and one year of continental experience—seven months in Germany (in an office, and in the works of a glove manufacturer) and five months in Denmark, in a modern spinning mill, by the courtesy of Mr. H. Windfeld-Hansen, a member of the Institute. The College course included Spinning, Weaving, Dyeing, Engineering, and Economics, and a Business Administration Course comprising seven subjects. Successful in his studentship, Ratcliffe was awarded the Associateship of the Textile Institute in 1932, passing the Examination in General Textile Technology with special merit. In addition to his technical attainments under the Institute Scholarship, he has successfully studied the German, Danish, and French languages. His abilities in the latter connection, it is understood, formed an important consideration in regard to his appointment. Announcement of the appointment was made at the October meeting of the Council of the Institute at Manchester.

Textile Institute Diplomas

Elections to Fellowship and Associateship have been completed as follows since the appearance of the previous list (September issue of this *Journal*)—

FELLOWSHIP

MATTHEW, John Alexander (Belfast)

ASSOCIATESHIP

BEEVERS, Harry (Elland, Yorks.)

BIBBY, Andrew (Derby)

BINNS, Sydney (Rochdale)

BREAKELL, William (Oldham)

BROOKSBANK, Harry Raymond (Bradford)

FOGG, Frederick William (Nottingham)

GRAHAM, William (Blackburn)

HAIGH, Harry (Bradford)

HODKIN, Thomas (London)

IBBETSON, Frank (Bradford)

ICKRINGILL, James Rufus (Keighley)

LAIDLAW, David (Hawick)

LAITHWAITE, Herbert (Oldham)

LINDLEY, Fred Beaumont (Paisley)

MOSS, Arthur Stanley (Renfrewshire)

PICKUP, William (Preston)

PRICE, Frederick Charles (Heanor, Notts.)

SCHOLES, Tom (Hyde)

TOWLE, William Henry (Loughborough)

WALKER, Walter (Bolton)

The late Mr. Thomas Woodhouse

After only a few years of retirement, following upon a great stretch of service in textile education, the death has taken place at Blackpool (on the 9th October) of Mr. Thomas Woodhouse, formerly head of the textile department of the Dundee Technical College. Mr. Woodhouse was a Foundation Member of the Textile Institute and was elected a Fellow in 1926. He will be best remembered for his indomitable energy and outstanding enthusiasm in the cause of textile technical instruction. His output of text-books and technical articles over a long period of years represents a stupendous contribution which earned for the author a world-wide reputation. Among his best-known text books are—"The Finishing of Jute and Linen Fabrics"; "Jacquards and Harnesses"; "Jute and Jute Spinning" (with P. Kilgour); "Yarn Diameters and Cloth Structure" (with A. Brand); "Jute and Linen Weaving" (with T. Milne). Even subsequent to his declared retirement, Mr. Woodhouse continued his interest in textile technology and only two years ago was nominated and elected to the Council of the Textile Institute. At the October meeting of the Council, the deepest regret was expressed on account of the passing of so distinguished a member of the textile teaching profession.

Institute Membership

At the October meeting of the Council, the following were elected to Membership of the Institute—A. W. Anderson, Deanfield House, Londonderry, N. Ireland (Managing Director, A. R. Anderson & Co. Ltd.); J. L. F. McDowell, "Niaroo," 76 Suffolk Avenue, Derby (Technological Assistant, British Celanese Ltd.); G. D. Pratt, 1429 Bishop Street, Montreal, Canada (Technical Service, B. Laporte Ltd., Luton); J. S. Seville, 408 Huddersfield Road, Oldham (Stripper and Grinder, Orb Mill Co. Ltd.). *Junior*—D. A. Brook, 6 Layton Avenue, Mansfield, Notts. (in training for managerial post); F. Cheetham, 3 Bank Buildings, Milford, near Derby (Chargehand, Jacquard Trimming Looms and Fringe Department, English Sewing Cotton Co. Ltd.), H. D. Herald, Brentwood, Accrington, Lancs. (Textile Apprentice); L. Knoop, Halliwell House, Church Road, Bolton (Textile Student); A. Peck, 105 Beeston Road, Leeds 11 (Textile Student); T. N. Pu, 24 Kempnough Hall Road, Worsley, Manchester (Textile Student); J. Wale, 44, 11th Avenue, Lowhill, Wolverhampton (Laboratory Assistant, Courtaulds Ltd.); P. Watkinson, 43 Wigan Road, Deane, Bolton (Trainee, Sunnyside Mill, Bolton); T. Y. Wu, 24 Kempnough Hall Road, Worsley, Manchester (Textile Student); L. Yuen, 24 Kempnough Hall Road, Worsley, Manchester (Textile Student).

REVIEWS

The Textile Student's Manual. By T. Welford. Published by Pitman & Sons, Ltd. (Pp. xiii + 221, with 82 Figs. and Index. 7s. 6d. net.)

This handbook is an example of a class which, from their regular occurrence, during the past few years, might be aptly described as the textile student's "hardy manuals." Indeed, so bountiful is the harvest becoming that, instead of facilitating the student of textile technology in his choice of text books, there is the danger that a superabundance of such books might prove to be an embarrassment rather than a help.

The present manual, however, will be welcomed by all who wish to glean—to quote the sub-title—"An outline of all textile processes, from the origin of the fibre to the finished cloth, and a handbook to every branch of the textile industry." This might appear to be a big claim for so small a book to comprise "*all* textile processes," and "*every branch* of the textile industry," but the author adheres literally to the title and gives no more than an "outline" of all the processes involved, from the picking and ginning of the raw cotton; the preparation of flax and all the chief types of other bast fibres of commerce; wool; silk; and rayon; the spinning of each class of material into threads, both plain and fancy; the weaving and knitting of these threads into fabrics of every type, including

net lace textures, plush fabrics and carpets; the bleaching, dyeing, and finishing of textile fabrics; and calico printing by the various well-known methods.

In a book embracing such an extensive range it is pardonable if slight errors may inadvertently have escaped the vigilance of the author, or even if the information given is not always strictly in accordance with practical experience. For it is quite unreasonable to expect from any one individual either a personal experience of, or even an intimate practical acquaintance with, the alpha and omega of each and every single phase of textile technology. Still, where comparatively simple measurements of the convolutions, length, and diameter of cotton fibres are concerned, it is surprising to find it stated (on page 8) that "In a good Sea Islands cotton, which is the finest cotton grown, the twists (i.e. natural convolutions) may be as many as 250 to the inch, whilst the average is about 150 to the inch." Also, "the length (of cotton fibres) varies from $\frac{1}{2}$ in. in the poorest Indian to $2\frac{1}{2}$ in. in Sea Islands. The average diameter of a medium size cotton fibre is about $\frac{1}{1000}$ of an inch, although the finest Sea Islands may measure only $\frac{1}{1000}$ in. Some idea of its weight can be gathered from the fact that it takes nearly 150 million fibres to weigh 1 lb. avoirdupois."

With regard to that physical feature of cotton fibres which, in company with most writers, the author unfortunately describes as "twist," this is not actually "twist" in the same sense as the actual "twist" of either a single spun or a folded (i.e. a two or more ply) yarn or thread. The convolutions of cotton fibres which endow cotton with its most valuable spinning property are the natural convolutions which occur in reverse directions in the same fibre, and is caused by the irregular collapsing of the cell wall of the hollow cotton hairs (or fibres) as these develop, ripen, and mature within the cotton pod, and while they are under such degree of turgidity, due to the presence of the cell-sap, that the turning or twisting of the individual fibres would be a physical impossibility. It may also be pointed out that the occurrence of these convolutions in full developed fibres rarely exceed an average of 100 per inch. As regards the staple length, and the diameter of cotton hairs, a maximum length of $2\frac{1}{2}$ in. for Sea Islands, and a diameter ranging from about $\frac{1}{1000}$ in. for African, to $\frac{1}{1000}$ in. for Sea Islands cotton, would have been more nearly correct.

In view of future editions of this useful manual being required, it may be helpful to indicate one or two minor errors, for correction. Thus, in Fig. 53, page 145, the letters "CC" indicate "lease" rods, not "leash" rods. Likewise, the letter "F" indicates the "reed," not a "comb." The two twill weaves, Figs. 65 and 66, on page 155, are not "herringbone" twills, but simply the ordinary, regular 2 and 2 ($\frac{2}{2}$) or "Harvard" twill, running in reverse directions as right-hand and left-hand twill weaves respectively. The "herringbone" effect would result only by bringing these two twill weaves close together, without the intervening space; as they now stand, they tend to puzzle the student, as also would Figs. 67 and 68, on page 155, representing a "weft-face satin" and a "honeycomb" weave respectively. Instead of giving the broken and imperfect four-end satin weave as an example of the satin structure, either the 5-end, 8-end or 10-end regular and perfect satin weave structures would have furnished much better and more typical examples of this fabric structure. Again, the 6-end honeycomb weave would tend to perplex a student by conveying the impression that this weave, as here indicated on point paper, actually repeats on 8×8 ends and picks, instead of 6×6 ends and picks.

H. N.

Baumwollgewebe und Gardinenstoffe. By W. Spitschka and O. Schrey. (227 pp. and index.)

This book is the second part of the fourth volume of the series edited by Dr. R. O. Herzog and published by Julius Springer, Berlin (RM 30). This is a book which may warmly be commended not only to students but to those actively engaged in the industry whether as managers or overlookers; is divided into three parts, the first dealing with cotton cloths, the second with curtain and lace fabrics, and the third a collection of cloth samples, 96 in number, illustrating the different types of fabrics described in the first part. The book is written to describe the various weaves and the production of these cloths on the loom and although a small chapter on the loom, as a machine, is provided a knowledge of the mechanism of the plain, dobby, and Jacquard looms is necessary to appreciate the book fully.

The first sub-section deals with calculations respecting take-up, contraction of the warp and weft, average counts, etc. These are well described and are very

practical, but it is not pointed out that it is necessary to make allowance for contraction when calculating the average counts of doubled yarns. The calculations are made more involved by the necessity of introducing metric and French counts.

Now follows a description of the various weaves. In many cases the actual samples of cloths given are analysed, the proportion of colours, the length of the beam or beams where more than one is required, and all other factors essential to the production of the cloth on the loom; this section of the book deserves special mention. Section E describes raised pattern weaving, plain, dobby, and jacquard weaves, double cloths, damasks, piqués, and lenos. The latter are well described with good illustrations, but no distinction is made between the Bedford cord and the piqué, and the author fails badly in not pointing out the essential differences, both in price and quality, between the two.

The book goes on further to describe very exhaustively those fabrics delivered in the grey state, cotton dress materials, cotton linings, cloths for embroidery work, furnishings, and curtains and cotton velvets. The actual cloths at the back of the book make the whole very easy to follow.

The second part deals with what in this country is associated with the Nottingham trade. It differentiates clearly between single-tie, double-tie, and Swiss-tie combination. The five-thread system, a new invention of the Wurtenburger Gardinen Weberei, L. Joseph & Co., and A. C. Stuttgart is also described.

One arrives at the end of the book well satisfied with the time spent on it. The style is good and the German is not too technical. The arrangement makes reference easy and the book should appear in all good textile libraries. A. R.

British Colour Council: Autumn Season's Colour Cards for Cotton, Woollen, and Hosiery.

The cards issued by the British Colour Council appear to provide a form of forecast which should become more and more appreciated by the interests concerned, as there can be no doubt that the ranges of shades have been selected with both considerable amount of care and good judgment. It would be a tremendous advantage if these forecasts became readily and commonly accepted. The colour cards to hand are accompanied by explanatory notes and the probabilities of vogue are judiciously discussed. Mr. Robert F. Wilson, the general manager of the Council, provides well-reasoned notes for the conclusions reached and it is an interesting feature of the colour forecast generally that there is definite relationship considered between different sections. For instance, trimmings are specially considered in relation to colour of furs. In regard to shades for hosiery, also, consideration is given to shades which are likely to be popular in footwear. A most arresting feature of these forecasts appears to be that of the special consideration given to the correlation of colours for the various sections of production so that the ensemble effect may be readily acquired. P. A.

Le Coton en Afrique Tropicale. By Paul E. A. Janssens (in collaboration with W. J. Lugard). Ateliers R. Bausart, Brussels. (402 pp. 14 belgas.)

This book will lack appeal to English readers because the description, so far as it refers to the British Colonies in Africa, contains little that would be new to them. They will naturally not think of looking in a book like this for a copy of the Charter of Incorporation of the Empire Cotton Growing Corporation. It will be noted that South Africa and Egypt are not included in the book.

Where it would have been of great use to English readers is in the treatment of the cotton growing areas belonging to other European countries in Africa, but the description of these areas consists too largely of reproductions of official regulations. Perhaps the most interesting part is the description of the Government markets in certain of the colonies where fixed prices prevail. The bibliography is remarkable both for omission and commission. Sir George Watt is described variously as Sir George, Sir P., and Sir John. J. A. T.

Kunstseide. By E. A. Anke, E. Eloed, G. v. Frank, A. Havas, L. Moenkemeyer, E. Raemisch, H. Suida, and A. Zart. Published by Julius Springer, Berlin. (321 pp. Price 31.50 RM.)

This is the second edition of the seventh volume of "Technologie der Textilfasern," edited by R. O. Herzog, who considers a new edition desirable in view of the great development of the subject since the first edition was published some years ago.

The first noteworthy difference in the present edition is that the section on the colloid chemistry of artificial silk has been removed and transferred to the new edition of the first volume of the series. The individual authors of the various sections are, therefore, enabled to give more space to technical matters, thus the section on acetate silk has been increased by a chapter on the recovery of acetic acid.

In spite of this the impression formed from reading is that the book still suffers from the editor attempting to cover too large a field in one volume; for instance, the space devoted to Chardonnnet silk seems out of proportion to its present industrial importance, while viscose and acetate silk suffer accordingly, with the result that technically important details are overlooked or vaguely stated. For instance, the time required for xanthation is not stated and the time required for the "ageing" of soda cellulose is given as "etwa 3 Tage" (p. 12).

Apart from such details the book is excellent as far as it goes; the descriptions of the processes are very lucid and copiously illustrated by numerous photographs and diagrams. The sections on the after-treatment of artificial silk contain a good deal of useful information. The final chapter on the Economics of the Artificial Silk Industry has been brought up to date and makes very interesting reading.

R. G.

PUBLICATIONS RECEIVED AND ADDED TO THE INSTITUTE LIBRARY

The Cottage Textile Industries of Kashmir and their Prospective Development.

By Aldred F. Barker, University of Leeds.

This beautifully printed report was made to the Kashmir Government following an official visit by Professor and Mrs. Barker during the summer of 1931. A separate report was prepared upon Sheep-breeding and Wool-growing of Kashmir, this one deals specifically with the cottage textile industries. After describing the various textile processes practised in the cottages and small factories of Kashmir and analysing each in comparison with devices and machines in use elsewhere, the report deals with (Chapter IV) The Organisation of the Textile Industries of Kashmir; Chapter V, The Standard Productions; Chapter VI, Special Textile Productions; Chapter VII, Hand Spinning and Weaving *v.* Machine Spinning and Weaving; Chapter VIII, Suggestions; Chapter IX, Evolution of Cottage Industries along modern lines; and Chapter X, Special Recommendations. The report is of great interest, and the recommendations made worthy of serious consideration.

Manchester Municipal College of Technology.

Prospectus of short courses of lectures and laboratory work to be given during the Summer, 1933. These cover Engineering, Building, Chemistry, Textiles, Printing, Mathematics, Physics, Industrial Administration and Mining.

Empire Cotton Growing Corporation.

Report of the Administrative Council of the Corporation submitted at the Twelfth Annual General Meeting on 26th May 1933. Contains brief account of recent tour by Sir Richard Jackson in South Africa, Rhodesia, and Nyasaland.

Imperial Institute.

Annual Report for 1932 by the Director, Sir William Furse, to the Board of Governors. Covers an account of the activities of the three branches of the Institute—intelligence, laboratory investigation, and education.

The Drapers' Diary and Year Book, 1933. Published by the *Draper and Drapery Times*, London. 47th annual issue. (Price 7s. 6d. net.)

This appears to be a very useful directory for those engaged in the distributive end of the textile industries. It covers reference lists of Trade Organisations; Benevolent Institutions; Postal Rates and Charges; Guides to Income Tax and Trade Boards; Railway Charges; Résumés of the Landlord and Tenant, Goods, Business Names, and Rent Restrictions Acts, and an annotated guide to Public Companies engaged in the Draper Business.

"Facts about Seamless Cork Cots."

A booklet issued by the Armstrong Cork Company, Lancaster, Pa., U.S.A.

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PROCEEDINGS

Lancashire Section

Jointly with the Manchester and District Section of the Institution of the Rubber Industry, the members of the Lancashire Section of the Textile Institute took part in a meeting held at the College of Technology, Manchester, on the evening of October 16th, when papers were contributed on "Cotton as a Raw Material for the Rubber Industry" by Mr. W. H. Reece, B.Sc., and "Cotton Fabrics for the Rubber Industry" by Mr. Fletcher Chadwick, F.T.I. Mr. Reece explained that reinforcement of rubber with cotton was carried out where flexibility and high strength were required but where the change in dimensions under load was to be limited. Taking transmission belts, conveyor belts, and hose as examples, Mr. Reece discussed the treatment to which the cotton was subjected in the rubber factory. It was necessary not only to study the stresses involved and to decide upon the structure most suitable, but also to give due consideration to the possible changes in structure during manufacture in the rubber factory.

Mr. Chadwick dealt with the selection and treatment of cotton and described methods of determining the values of the physical properties, specially referring to the characteristics of various grade and staple. Reference was made to short fibres and their removal, fibre weights, maturity tests, and their influence in preparation and spinning. A list of fibre losses showed that in some cases only 60% of the cotton bought is converted into cloth, the remaining 40% being lost in the processes. Dealing with heat generation and the effect of twist, Mr. Chadwick described twist in yarn as the means by which fibres were joined together, resistance to friction added, and resiliency secured. Research work and co-operation increases the responsibility of the cotton manufacturer, and what comprises a satisfactory load factor terminating in high fatigue value resulted from the properties built into the fabric following carefully selected cotton.

Various methods of inserting twist and the subsequent weaving of the yarns into heavy fabrics used by the rubber manufacturer were enumerated as well as methods of testing for physical properties.

One of the most remarkable advances made in the Rubber Industry, said the lecturer, was the improvement in tyres which two years ago were said to be too good at 15 to 20,000 miles whereas to-day they had records of tyres doing 120,000 miles on omnibuses.

Discussions followed and the Chairman (Mr. S. Brazier) said the amount of cotton now used in the rubber industry was tremendous and for this reason alone he thought it was all to the good that representatives of both the interests should be brought together.

Mr. T. E. Mitchell (Rochdale) agreed that co-operation was most desirable.

Mr. Sopwith suggested possibilities in the use of latex in connection with belt manufacture and, thereby, avoidance of the drying process. As to tendering in

the course of processing in the rubber factory, he suggested the possibility of special treatment for prevention of tendering prior to operations in the rubber factory.

Mr. Chadwick referred to the great improvements effected in tyre manufacture. Regarding the tyre as a form of belt, there seemed room enough for improvements in beltings.

Midlands Section

VISIT TO FORT DUNLOP WORKS

A party of members of the Midlands Section of the Institute visited the works of the Dunlop Rubber Co., at Fort Dunlop, Erdington, Birmingham, on the afternoon of Thursday 19th October. A tour of inspection included that part of the factory engaged in the production of pneumatic tyres and also the new section devoted to the production of "Lastex" under the control of the Dunlop-Revere Thread Co. Ltd. After the inspection, the party were entertained to tea in the visitors' reception hall, where a special display of fabrics and garments in which Lastex was incorporated had been provided. Mr. R. Truesdale A.T.I. and Mr. T. M. Lawson, F.T.I., contributed short addresses (1) in relation to tyre construction, and (2) to Lastex yarn, respectively.

No. 1 Statement—Tyres

You have just made a tour of one of the most modern, if not the most modern, tyre plant in the world. You will, no doubt, have been struck during your visit by the importance of cotton in the manufacture and its ultimate use in tyres. Going back the relatively short period of 45 years when John Boyd Dunlop made his first pneumatic cycle tyre, in which was used strips of linen sailcloth, we have arrived at the stage when commercial tyres are in use as large as 15 inches in cross-section.

In the early days of tyre manufacture cross-woven plain fabrics were first used, and although after a few years the cord arrangement was used in cycle tyres, it was many years before the fine cord type in general use to-day was introduced in passenger car vehicles. One can in general date the displacement of canvas as a post-war achievement. From small beginnings the tyre industry to-day ranks amongst the important users of cotton. It was estimated that over 500,000 bales of cotton were used per annum in the manufacture of motor and truck tyres alone, mainly of the better growths and staples.

In an average size of tyre the weight of cotton to other materials is roughly one part of cotton to four parts of other ingredients by weight. Typical examples of the quantity of cotton used in tyres are the following—in a 5.50-19 passenger car tyre there is 4½ lb. of cotton; in a 9-in. truck tyre there is 30 lb. of cotton, and in a 15.00 as much as 65 lb. During the last decade, as most of you are aware, the mileage per tyre has been considerably improved, and it may be said that to-day the same weight of cotton in the better makes of tyres is capable of giving roughly three times the mileage formerly obtainable.

These changes have mainly resulted from intensive study of the type of stressing cord must withstand in tyre service. In many instances it has been found necessary in producing the desired characteristics to make radical departures from accepted principles of cotton manufacture. A tyre cord must possess the following fundamental characteristics.

Fatigue Resistance—Cord must be very flexible, and be capable of withstanding varying stresses of small intensity millions of times.

Stretchability—Cord must be "stretchable" to a predetermined degree and at the same time relatively "elastic". Its power-loss factor must be small.

Impact Strength—A high impact strength is an obvious necessity.

Adhesion to Rubber Compounds—The surface configuration of the cord and the fabric structure must be such as to enable rubber compounds to cling and hold under tyre service conditions.

Resistance to High Temperatures—During vulcanisation, tyres are subject to temperatures of 150° to 160° C. for periods up to 2 to 3 hours. In some services tyres often run at temperatures of 80 to 90° C.

Moulding Efficiency—Cord constructions and fabric structures must be capable of moulding to tyre shapes without the formation of creases, folds, etc.

Safety Factor—The cord used for any specific purpose must possess a high safety factor over the working stresses to which it is subject in the tyre.

As a result of continuous research on the mechanical properties of cotton and its conversion into tyre cords we are able to produce tyres in which the foregoing characteristics are so balanced as to give exceptional tyre mileage performance. For ascertaining the correct condition of cord for tyres it is necessary to study the stresses to which cord is subjected within the tyre. It therefore becomes imperative that cotton must be considered not from the standpoint of a cotton manufacturer but from considerations of what is needed in a tyre, consequently the basis of cotton control is one necessitating close liaison between the tyre factory and the cotton mills. We are producing tyres not cotton. Cotton to the tyre factory is partially processed material, and only is it possible to produce tyres of maximum performance from given materials by exercising control of materials and manufacturing processes right from raw material selection.

Our experience is that it is practically impossible to get tyre cord exactly alike in physical properties from different tyre cord producers, and as it is so essential that each cord should function in the tyre along with its neighbour, it is necessary that the physical properties of every cord should be as similar as is possible. This position was realised by Dunlop many years ago, with the result that the whole processing of cotton and tyre manufacture were organised with a single purpose of producing cord to meet the service needs of tyres; and to-day every ounce of cord used in Dunlop tyres is produced at our Rochdale cotton mills.

It is absolutely essential in the manufacture of the best tyres that continuity of supplies of cord of identical types as well as other things should be guaranteed if quality is to be maintained. Research, continuous testing and improvements in factory methods proceed apace, and no effort is spared to maintain and improve the lead in quality which we hold and of which we are proud.

No. 2 Statement—Lastex Yarn

Lastex yarn contains a core of lactron, which is produced by an extrusion process, giving a thread of very uniform cross-section and, consequently, uniform tension properties. By this extrusion method, very fine yarns can be produced, capable of being woven or knitted in like manner to other textile yarns.

The lactron core can be covered with cotton, wool, or silk, and the resulting lastex yarn is made with diameters as fine as 25's cotton. It is made with varied degrees of elongation, so that it is suitable for warp or weft or knitting machines, warp knitting machines, braiding machines, lace making machines, embroidery, etc., and no structural changes of the machines are necessary. It has very good ageing properties and will withstand laundering; in fact, lastex yarn has been subjected to a temperature of 240° F. for two hours with no marked change in its properties. Washing tests which have been carried out on fabrics containing

lastex yarn, have shown that the shrinkage of the fabric has been less in the direction of the lastex yarn than in the direction where there was no lastex yarn.

Up to now, it has been applied to woven dress goods, knitted dress goods, suitings, woven and knitted underwear, net for brassieres, tops of half-hose to obviate the need for suspenders, gloves, hats, caps, bathing costumes, etc.

It is used from a three-fold point of view—

(a) To produce novelty effects, such as permanent pleats, crimp effects (more crimp can be obtained by the use of lastex yarn than by the use of crêpe yarn and such crimp is permanent).

(b) It can also be used to produce a stretchable fabric which can be used to make up a skin-tight garment, which, at the same time, is comfortable to the wearer, such as underwear or bathing costumes. It can be used to produce a fabric which is capable of being stretched both ways, so as to give enhanced comfort to the wearer.

(c) It can be used to exert a retractive influence on the fabric so as to hold the shape and prevent any sagging or bagging.

Yorkshire Section

SOCIAL GATHERING AT BRADFORD

In connection with the Yorkshire Section of the Institute, the Chairman of the Section Committee, Mr. T. H. Robinson (Bingley) kindly invited members to a social gathering at the Midland Hotel, Bradford, on the evening of Thursday, October 26th. There was a good and representative attendance and the proceedings proved most enjoyable.

The Chairman welcomed the members and trusted the Section would benefit by the opportunity for fraternisation which a gathering of this description provided. He was glad to witness a good attendance of members and, amongst the company, several outstanding supporters including Mr. John Emsley (Past-President), Mr. Henry Binns, Mr. R. J. H. Beanland, Mr. Gerald Gaunt, Mr. J. Dumville, Mr. John Robinson, and others. Mr. A. Saville had sent a message of regret on account of inability to attend. Continuing, the Chairman said that Dr. S. G. Barker had kindly promised to address the meeting. Alluding to the Section's programme of forthcoming meetings, he was pleased to announce that Professor A. T. King (Leeds) had promised a contribution on "The Sulphur Content of Wool", whilst there was to be a joint meeting with the Society of Dyers and Colourists. Meetings were to take place at Keighley, Huddersfield, and Leeds, at which addresses in relation to the Institute's Diplomas Scheme would be contributed by Dr. Speakman, Mr. F. W. Barwick, and others.

After these announcements, the Chairman called upon Dr. Barker, who contributed an address quite appropriate for a social gathering. He said that wool remained the dominant textile material for bodily clothing and he saw no reason why that position should not be maintained. So far as scientific research was concerned, there was still a vast field for exploration if the industry could realise the fact and make provision for the work to be adequately pursued. It was important that workers within the industry should acquire a better outlook in relation to technical and scientific advancement and our educational system ought to do a great deal more towards bringing this about.

Mr. John Emsley, J.P., contributed a few remarks and said that whilst the scientists had abundant achievements to their credit yet he sometimes hoped that they could achieve much more in the direction of securing increased employment for the masses.

During the evening refreshment was served and musical items contributed.

NOTES AND NOTICES

Obituary Announcements

A staunch supporter of this Institute has been removed by the death of Mr. T. Fletcher Robinson, J.P., of Salford, which took place suddenly at his residence at Pendleton, near Manchester, on Tuesday 14th November. Mr. Robinson devoted a great deal of time to Institute affairs and was for many years an active member on many committees. A Foundation Member of the Institute, he occupied the position of Honorary Treasurer for a period of 15 years commencing in 1914, and it was largely due to his efforts that the financial resources of the organisation were effectively conserved. At one time, he was the head of an engineering firm concerned with the production of machine tools. Later, he engaged as an exporter of silk yarns, ultimately retiring in 1928 on account of ill-health. He was a governor of the Salford Royal Technical College, and took a profound interest in technical education for a great number of years. In 1930, the Textile Institute awarded him the Institute Medal in appreciation of his services to the organisation.

We have also to record the death of Mr. Albert W. H. Ostheide, representative for Great Britain of the Unionmatex, Berlin, which took place suddenly at Leeds on the 9th November. Mr. Ostheide had been a member of the Institute since 1925, and attended many meetings and conferences.

TEXTILE INSTITUTE ANNUAL COMPETITIONS

Design and Structure of Fabrics

The Competitions Committee of the Institute met on 16th November to receive the final reports of the Adjudicators and to prepare the final list of successful competitors. This list is published as follows—

(A) COMPETITION—WOVEN FABRICS

First Prize—Not awarded.

Second Prizes (each £25 and Certificate)—Stanley Wilkinson (Keighley), Bradford Technical College; Frank Warburton (Barnoldswick), Nelson Municipal Technical School.

Third Prize (£15 and Certificate)—Stanley Potts (Radcliffe Technical College).

Prizes of £5 each—Norman Pearson (Chorley Technical Institute); William Pickles (Colne Evening Technical School); John Norman Swales (Clitheroe), Manchester College of Technology; R. M. Halliday (Bradford), Leeds University; F. Gaukroger (Burnley Municipal College).

(B) COMPETITION—NOVELTY FOLDED YARNS

First Prize (£7)—Arthur Stanley Hill (Bradford Technical College).

Second Prize (£5)—J. Donald Spencer (Halifax), Bradford Technical College.

Third Prize (£3)—T. W. Holt (Burnley Municipal College).

Extra Prize (1 guinea)—Wm. George Doidge (Blackburn Municipal Technical College).

(C) COMPETITION—NOVEL WOVEN FABRIC

First Prize (£7)—Andrew Millin (Hyde), Manchester College of Technology.

Second Prize (£5)—John Norman Swales (Clitheroe), Manchester College of Technology.

Third Prizes (each of £2)—Eric W. Kenyon (Huddersfield Technical College); Thomas Mellor (Huddersfield Technical College).

(D) COMPETITION—WOVEN FABRIC (Special Students)

First Prize (£5)—Allan Sutcliffe (Keighley Technical College).

Second Prize (£3)—Robert Atkinson (Burnley Municipal College).

Third Prize (£2)—Thomas Alfred Graham (Bradford Technical College).

(E) COMPETITION—KNITTED FABRIC

First Prize (£7)—Constance Mary Rimmington (Leicester Colleges of Art and Technology).

Second Prize (£5)—Kathleen Beatrice Gurr (Leicester Colleges of Art and Technology).

Third Prize (£3)—Mary Roberts (Leicester Colleges of Art and Technology).

(F) COMPETITION—DESIGNS FOR PRINTED FABRICS

CLASS I—DESIGN FOR FURNISHING FABRIC

First Prize (£10)—Noel S. Leaver (Simonstone, near Burnley), Manchester Municipal School of Art.

Second Prize (£5)—Phyllis M. Lismer (Enfield, Middlesex), Hornsey School of Art.

CLASS II—DESIGNS FOR DRESS MATERIALS

First Prize (£10)—John Robert Kemp (Manchester School of Art).

Second Prize (£5)—Mary S. E. Coultas (Dewsbury School of Arts and Crafts).

Institute Examinations

At the November meeting of the Selection Committee, which deals with applications for the Fellowship and Associateship of the Institute and controls the conduct of examinations connected therewith, consideration was given to a report of the percentages of marks secured by candidates in the last nine examinations in General Textile Technology (now Part II of the examination in relation to applications for the Associateship). Records show that the lowest percentage has occurred in Section IV (Conversion of Fabrics into Finished Materials) and the highest in Section II (Conversion of Fibres into Finished Yarns). Whereas from 1928 to 1930 the percentages showed somewhat marked fluctuations, from 1931 to 1933 they were fairly constant. In the case of the last examination, held in June of the current year, the Board of Examiners called the attention of the Selection Committee to weakness of attainment in Sections IV and V, and particularly stressed the marked weakness of many candidates in grammar and composition. The Board agreed that, generally, the scripts showed most undesirable weaknesses in handwriting, spelling, punctuation, and grammar. A special survey was subsequently made of the scripts covering the last four examinations (Part II). This indicated that of 93 scripts examined (those of four foreign candidates being excluded) only 17·2% were graded as "excellent" or "good" as regards the standard of grammar and composition, 73% were graded as "fair", and 9·7% as "poor". Since 64 of the candidates had had secondary or higher grade education, and as the average age was 26 years and 8 months, the Board were strongly of the opinion that a higher standard of grammar and composition should have been attained.

The Selection Committee agreed that these details should be recorded for the guidance of teachers in the textile departments of the various colleges and schools.

Design and Structure of Fabrics

The prize distribution and exhibition of specimens submitted in connection with the Annual Competitions of this Institute has been fixed to take place at the headquarters premises at Manchester on the afternoon of Saturday December 2nd. The (A) Competition, promoted as a result of the operation of the Crompton Memorial Fund, continues to occupy chief place in the scheme of competitions. This event is associated with important prizes for the production of collections of woven fabrics—16 specimens, 6 of which must be all cotton. All of these specimens must have been woven by the competitors at a technical college or school. There are now six separate competitions and, for the first time,

a contest has been provided in relation to designs for printed fabrics. The entries recorded are as follows—Competition (A) Woven Fabrics, 12; (B) Yarns, 9; (C) Special Woven Fabric, 18; (D) Woven Fabric (special students), 16; (E) Knitted Fabric, 16; (F) Designs for Printed Fabrics, (two classes), 21 and 14. At the last meeting of the Competitions Committee (November 3rd), the gratifying announcement was made that an anonymous gift of £10 had been received in favour of the Competitions Fund, the gift to be annual at the pleasure of the donor. Mr. Frank Wright, Chairman of Council, stated that he would contribute £10 and would also make endeavour to secure further donations for prizes. For the gifts announced, Mr. John Crompton (Chairman) expressed warm appreciation in the name of the Committee.

London Section Visit to Mills

At a meeting of the London Section of the Institute on the evening of 27th October, the Chairman of the Committee, Mr. John Howard, F.T.I., presided, and a discussion took place on matters of interest in connection with the recent visit to mills and other textile establishments in the Manchester district. There was a good attendance, including members of the visiting party, and the discussion and comments were regarded as helpful and interesting. A hearty vote of thanks was passed to the Institute for the arrangements made and hospitality afforded. The Council, at last meeting, on Wednesday 15th November, received the intimation of the vote with thanks and recorded their appreciation of the services and generosity of the Chairman, Mr. F. Wright, and Mr. F. Nasmith, on the occasion of the visit. The Secretary was instructed to acknowledge the thanks of the London Section.

With further reference to the London Section, the Honorary Secretary of the Section Committee, Mr. Arthur R. Down, was married on Wednesday, 22nd November, and the Section Committee forwarded a cheque representing subscriptions from members of the Section and other friends.

Meetings of Other Organisations

In each month's issue of this *Journal*, announcements of Institute meetings arranged are prescribed and a list of meetings under the heading of "Other Organisations" is also provided. Occasionally, inquiries reach the Institute as to whether certain meetings of other organisations could be attended by Institute members. It is suggested that members desirous of attending should write the Secretary of the promoting organisation asking for permission. If the address of the Secretary is not known to the applicant then the letter should be addressed c/o The Textile Institute, 16 St. Mary's Parsonage, in which case it would be re-directed and forwarded. Postage to cover reply should be enclosed with the letter.

Institute Employment Register

The following announcements are taken from entries in our Register of Members whose services are on offer. Employers may obtain full particulars on application.

No. 106—Desires position as Designer, Stylist, or Assistant Manager.

No. 107—Administrative position in the cotton industry at home or abroad.

No. 108—Representative for firm in Worsted Textile Machinery.

No. 109—Manager, Designer-manager, Assistant to Manufacturers, or Analyst and Tester.

No. 110—Mill Manager or Assistant Manager.

Jubilee Celebrations of the Society of Dyers and Colourists

October 12th 1933

To the Editor, "*Journal of the Textile Institute*", Manchester

SIR

One of the great features of next year's Jubilee Celebrations of the Society of Dyers and Colourists, is to be the publication of a volume dealing with the history, progress, and present position of every phase of the dyeing, dyestuff, and textile printing industries.

The contributors are of international repute, and the volume will certainly prove to be a world's landmark in the history and literature of the tinctorial arts and industries.

It is determined to make the celebrations next Whitsuntide the greatest event in the dyeing world, and this volume unique in its complete survey of our knowledge of dyeing, textile printing, and dyestuff manufacture.

There is doubtless much valuable matter which is in danger of being irretrievably lost and which closely affects our knowledge of dyeing and dyestuffs, and also concerning the history of the Society of Dyers and Colourists with its branches in every main centre of the dyeing industry in Britain, and its members in all parts of the world.

It will be of great value if these things can be brought to the notice of the above Society whether these matters be ancient or modern, British or foreign.

Yours faithfully

32 PICCADILLY
BRADFORD

(signed) GEO. G. HOPKINSON
Honorary Secretary

Textile Organisation's Jubilee

The Bolton and District Managers, Carders, and Overlookers' Association recently completed fifty years of existence and experience. Jubilee celebrations were conducted in the Co-operative Hall at Bolton on the evening of Saturday, the 11th November. The very large gathering which assembled clearly indicated the virility of the Association and the hearty enthusiasm of the members. In the course of the proceedings, which took the form of a dinner, followed by entertainment and dance, the President (Mr. Shepherd Holt) called particular attention to the wide scope of operations of the organisation. In addition to their lecture programmes, the organisation was concerned with the operation of a providential scheme of considerable importance. The Mayor of Bolton (Dr. Monks) attended and commended the efforts of the organisation. The founders, he said, were far-seeing men, and it was the duty of present-day members to carry forward and develop their objects in accordance with the progressive reputation of the town of Bolton. Mr. Cox, Director of Education, congratulated the Association on their achievements over the last half century, whilst Mr. J. D. Athey offered greetings and good wishes on behalf of the Textile Institute.

Textile Institute Diplomas

Elections to Fellowship and Associateship have been completed as follows since the appearance of the previous list (October issue of this *Journal*)—

FELLOWSHIP

HARRISON, William (Kilmacolm, Scotland).

ASSOCIATESHIP

LANCASHIRE, Cecil John (Leicester).

MIRZA, Yahya Shooshtry (Bombay).

SHROFF, Edulji Framji (Bombay).

WILLIAMS, John Guilfoyle (London).

Institute Membership

At the November meeting of the Council, the following were elected to Membership of the Institute—*Ordinary*, W. K. Hamilton, 28 Crags Avenue, Paisley Renfrewshire (Dyehouse Assistant, Piece Goods); H. Jones, The Firs, Derby Road, Sandiacre, near Nottingham (Director, Jones, Stroud & Co.); A. T. King, B.Sc. (Lond.), F.I.C., Textile Department, The University, Leeds (Professor of Textile Industries); G. E. Lever, 26 Arkwright Street, Tyersal, Bradford, Yorks. (Textile Designer, J. Emsley & Co. Ltd.); J. T. Murray, 4 Water Street, Manchester (Textile Machinery Agent); N. Morris, 164 Bromwich Street, Bolton (Assistant Spinning Manager, Eckersleys Ltd., Wigan); W. A. Sharpe, John Speight, Son & Co. Ltd., Broad Lane Mills, Laisterdyke, Bradford; R. Stockton, 214 Albert Road, Farnworth (Ring Overlooker); G. Ullmann, Ph.D., Tegetthoffstr. 7, Vienna 1, Austria (Consulting Textile Chemist and Engineer); J. E. Watmough, 12 Carr-bottom Road, Greengates, Bradford (Ring and Mule Spinning Overlooker, G. Garnett & Sons Ltd.); F. Wood, 13 Southern Road, Cowlersley, Milnsbridge, Yorks. (Technical Representative); *Junior*, P. J. H. Desplats, 39 Rue Péraudel, Castres (Tarn), France; M. Fariduddin, College of Technology, Manchester (Student); A. Livingstone, 18 Vine Street, Hollinwood, Oldham (Warehouse Assistant, Cop Packing); R. Robinson, 5 Beechwood Grove, Moorhead Lane, Shipley (Worsted Yarn Salesman); N. H. Weir, 170 Lister Avenue, Bradford (Woolsorting, Sanderson, Murray & Elder Ltd.).

REVIEWS

Education for Industry and Commerce in England. By A. Abbott, C.B.E. Published by the Oxford University Press. (5s. net.)

No one perhaps is more competent than Mr. Abbott to write a book under this title; and perhaps no book on the subject has appeared for many years that is better worth reading. It provides an extremely lucid statement of the haphazard development of technical education during the 19th century, it gives an admirable picture of the present condition of affairs, and it attempts a thought-provoking forecast of future developments. And the reader when he has finished the book will probably discover that he has, without knowing it, been through a more or less complete course in the philosophy of technical education, with all the difficult words left out and the jargon peculiar to such philosophies carefully disguised in the simplest of English. While the technical educationist will gain from its perusal a broader outlook over the whole field than he generally possesses, educationists from other camps will learn much of what to most of them is a more or less closed book and will be specially interested in the relationship between technical and other types of education. But the book will be of perhaps even greater value to industrialists and business men who, though keenly alive to the value of technical training, find themselves in need of guidance and concise information as to the various facilities available and their relationship to the industrial system.

Single industries are not treated separately in any detail; nevertheless the textile industry, which at the present time is contemplating important developments in dealing with its educational problem, will find much that is of great value. Education "for the more scientific industries", like engineering and chemistry, has developed on different lines from those of the "less scientific industries" like the textile and boot and shoe industries. The textile industry is, however, gradually, if slowly, developing a more scientific basis, and the training of its personnel must be modified accordingly. And it is not the training of the operator class alone that needs attention; readers of this book will realise the essential importance of suitable and adequate training for the managerial ranks. Unless these are provided with a sound scientific background and an appreciation of the scientific possibilities of their industry, the seeds of progress planted by textile research associations and the like must run a serious risk of falling upon stony ground. Lord Eustace Percy, in his introduction, describes the book as "a practical study of the most important social problem that confronts this country, in common with the whole industrial world, at the present moment."

The textile industry, as an important part of that industrial world, should give the book serious attention.

B.M.J.

Fundamentals of Fibre Structure. By W. T. Astbury, with an introduction by Sir William Bragg. Published by Humphrey Milford, Oxford University Press, London, 1933. (Pp. xii-187. Price 8s. 6d.)

In this small volume the author has succeeded in presenting a remarkably large mass of information resulting from work which has required patience and thought akin to that required of an astronomer. Indeed, the calculations and figures involved in this branch of X-ray science are of a nature which closely resembles many astronomical calculations. Lest the prospective reader, not being already interested in the study of X-ray analysis, be tempted to avoid the book in the fear that it may prove too abstruse or boring, it must be emphasised that he would thereby miss one of the most entertaining and valuable books that have been written on textile subjects.

Mr. Astbury has compiled the book from a series of his lectures, and he has written in a manner which makes it remarkably easy to read and understand. One obtains an impression, in reading the book, of the very great enthusiasm of the author for his subject, and this enthusiasm is transferred to the reader by the interesting manner in which he is made to progress by easy steps. He is led by stages from an excellent short description of the fundamental nature of matter and radiation to a striking mental picture of the internal structure of textile fibres. In this course, the author steps aside from his main theme, at appropriate stages, to explain the practical connection between the intricate structural systems of the fibres and technically important phenomena such as moisture regain, swelling, and tension effects. By this means one is given a clearer understanding of many textile problems which are difficult to explain without reference to the results of X-ray experiments. The difficulties which stand in the way of easy understanding of the subject are very successfully reduced by the numerous comparisons which the author makes with commonplace facts and figures, and the many excellent diagrams and photographs make it easy to form a mental picture of the structures described.

Mr. Astbury must be congratulated, not only for the excellent work which he himself has done in this branch of science, but also for the manner in which he has collected such a comprehensive mass of information into so readable a form. He has written a description of a difficult subject in such a way that even a reader with very little knowledge of chemistry or physics may understand all that the book contains. Either the novice or the expert in textile science will feel that he has learnt much of value from the book.

This book brings to mind the very great possibilities which lie in the application of X-rays to industrial problems and to pure science. It is to be hoped that Mr. Astbury will not be long before producing further volumes of equal quality to foster interest in this new method of research into old problems.

P.B.

Colour: A Manual of its Theory and Practice. By H. Barrett Carpenter. Third edition. Published by B. T. Batsford Ltd. (76 pp., Index, and xxv Coloured Plates. Price 9s.)

This work is the third edition of Mr. Carpenter's well-known book "Suggestions for the Study of Colour," published under a more suitable title, and with a new cover, which although too light for a text book and not very harmonious in colour brings it up to date with the modern movement for brighter bookbindings.

The book has been revised and entirely reset with well-proportioned margins which add distinction to it. Also many of the plates are vastly improved, the colour circle in particular (Plate II), providing a reliable colour chart of harmonies and contrasts. A comprehensive analysis given of the theory of colour relationships illustrated by diagrams should be of special value to students, teachers, and the designer of textiles, and may also guide the critic (buyer, salesman, or customer) in giving constructive criticisms when making a selection from coloured goods.

The most important feature of the new edition is an interesting Appendix consisting of fine coloured plates of fabrics and pottery of the eighteenth and nineteenth centuries from Eastern sources, reproduced by permission of Herr Heinrich Jacobs of Messrs. Hoffmann of Stuttgart. Plates such as these should act as an incentive for the further study of actual fabrics produced by people who knew little or nothing of the science of colour as discovered by European

scientists, proving that the theory of the causes of harmony, contrast, etc. was already practised as though by instinct by the carpet and silk weavers of India and China and the chintz printers of Persia.

We heartily recommend this book, the work of an enthusiast and deep student of the science and application of colour, whose teaching influenced art in industry as well as in the art school. E. R. D.

A.S.T.M. Standards on Textile Materials. Prepared by Committee D13 on Textile Materials. Published by the American Society for Testing Materials, Philadelphia, Penna., U.S.A. (\$1.00 net.)

The work of "Committee D13" is already well known outside the U.S.A. in its attempts to standardise the methods of testing textile materials and it is very convenient to have the whole, or at any rate the main, work of the Committee set forth so clearly in one volume. No attempt is made of course to cover the whole ground of testing, but the principal tests are described in sufficient detail for most commercial purposes, but particularly with the object of ensuring that different observers will use the same methods of testing when attempting to comply with those specifications upon which textile products are often purchased. The specifications adopted by the Committee for the supply of many textile products are set forth, including tyre fabrics and yarns, sacks, braids, sewing threads and certain asbestos products. The "tolerances" to be allowed above and below the standards are stated and there is a useful list of "definitions and terms".

Many of the specifications are "tentative" and the attitude of the Committee towards improvements is so well known that there should be no fear of that common complaint against standardisation whereby it is feared that progress may be impeded rather than hastened. It is not difficult for the expert to pick a hole here and there in the work of the Committee, but the mere fact that standardisation has been seriously attempted and brought up to practicable working conditions is an achievement to be most highly commended.

Our own Institute must appreciate the work of the Committee in having undertaken and carried out a task which we have envisaged for something like 20 years. Hitherto it has been "nobody's job" to standardise testing. It is a work for the whole textile community which could only be tackled by the very few who combine an intimate knowledge of the methods of testing with manufacturing and commercial experience. Hitherto the magnitude of the task has been such that the necessary handful of workers could not be got together and imbued with the energy necessary to do the work. The publication of this volume may well be an inducement to a further effort in this direction and the suggestion naturally arises for us to consider whether the general approval of our Institute might be given to the standards of the U.S.A. or whether the time has come to make any desired alteration in those standards for our own purposes and to adopt them in some modified form. The work of Committee D13 must make the work of any British Committee charged with textile standardisation very much easier, indeed perhaps almost automatic. J.H.L.

PUBLICATIONS RECEIVED AND ADDED TO THE INSTITUTE LIBRARY

"Industrial X-ray Service."

A brochure issued by Philips Industrial, Philips House, Charing Cross Road, London.

Ontario Research Foundation, Canada.

Report for the year 1932. Includes the report of the Department of Textile Research.

London School of Economics and Political Science. (University of London) Department of Business Administration.

The prospectus of the Department has been received. It details the facilities available for the 1933-1934 Session. The Department was established in 1930 as an experiment designed to provide an answer to the vexed question as to whether a specialised training could be provided which would impart the professional knowledge and administrative qualities of judgment and breadth of view generally agreed as desirable and essential for modern business. After two years of experience, admittedly not too long a period, the claim is made that the experiment was justified and the results obtained encouraging.

Fibres: A Summary of Figures of Production and Trade relating to Cotton, Wool, Silk, Hemp, Flax, and Jute. Compiled and published by the Empire Marketing Board. (H.M.S.O. Price 6d. E.M.B.H./C/6.)

The importance in international trade of cotton, wool, silk, hemp, flax, and jute may be gauged by their estimated total value which amounts to £1,195,000,000. Facts concerning them have been collected by the Empire Marketing Board and published in this report. The Board acknowledges the help provided by volumes of comprehensive international statistics compiled by such bodies as the International Institute of Agriculture, the United States Department of Agriculture, and the League of Nations. The report surveys the areas cultivated for the various fibres, and is a census for the world's sheep population. Each product is considered separately as regards its importance in export trade, its share in world exports and their distribution, whilst notes are given on the chief importing countries. Empire trade in each instance is treated as a whole, as are the United Kingdom imports. Variations of price due to qualitative differences or to world conditions are recorded.

Coir: Report on the Attributes and Preparation of Coconut Fibre. By S. G. Barker, Ph.D., D.I.C. Published by the Empire Marketing Board. (H.M.S.O. Price 1s. net. E.M.B. 71.)

Coir, the fibre in the husk of the coconut, has been made the subject of special research by Dr. S. G. Barker, who has drawn up a report on its attributes and preparation. The coconut palm covers nearly four million acres of land within the Empire, more than half the world acreage. Three-and-a-half million tons of coir for spinning were produced in 1931, but only 100,000 tons were used. Discrepancies such as this have led Dr. Barker to suggest that an attempt should be made to discover some means by which the fibre could be put to fresh uses at a reasonable cost. Both the present method of harvesting and the length of time necessary for soaking add to the expense of production. Experiments have been made with chemical methods of retting, which do not impair the quality of the fibre although they darken the colour. The problem appears to be not only to discover fresh uses for the fibre, but also whether it is possible to improve the existing cottage retting methods, or to introduce retting on a factory basis for large quantities and by chemical methods.

Individual Differences in Normal Colour Vision. A Survey of Recent Experimental Work. By W. O'D. Pierce. Published by the Medical Research Council (H.M.S.O. 2s. net. Special Report Series No. 181.)

The preface to this report states that "This review of the literature dealing with colour discrimination was made for the National Institute of Industrial Psychology by Mr. W. O'D. Pierce, a member of its research staff, with the aid of a grant generously given by the Rockefeller Foundation. It is published by the Medical Research Council on the recommendation of their Committee on the Physiology of Vision, in the hope that a summary of recent experimental work in different countries may be of assistance to investigators in this field. Problems of colour vision have much practical importance in industry, as also in the work of various Government Departments and especially of the Defence Services, and this survey of existing knowledge was prepared with a specific purpose in view. This was to collect information as to differences in colour vision among "colour normal" individuals, the object being the construction of tests for the selection and classification of workers on the basis of their colour sensitivity.

Colour Measurement: The Lovibond Tintometer. Issued by The Tintometer Ltd., Salisbury, England.

This brochure describes and illustrates an instrument for measuring and recording colour.

Stop Watches. Made by A. Arnold & Co., St. John Street, Clerkenwell Road, London E.C.1. Example review. Price 15s.

A stop watch (30-hour) graduated in 1/5th seconds and with side lever action has been received. It is submitted as suitable for laboratory and workshop use. It is guaranteed for three years. Under a three months' test it has proved a reliable timekeeper.

Davison's Textile Blue Book (Handy Edition). Issued by the Davison Publishing Co., 50 Union Square, New York, U.S.A. \$8.00).

This is the 68th edition of an easily-referred-to, and compact directory. It forms a useful addition to the reference library.

THE JOURNAL OF THE TEXTILE INSTITUTE

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No. 12

PROCEEDINGS TEXTILE INSTITUTE COMPETITIONS DISTRIBUTION OF PRIZES

The Institute Competitions for 1933 have now been completed and the prize-winning albums, fabrics, and designs determined by an Adjudicating Sub-Committee appointed by the Competitions Committee. The list of prize-winners appeared on pages p281-282 of the November issue of this *Journal*.

The following is the report of the Adjudicating Sub-Committee—

“Whilst the level of attainment throughout the whole of the competitions may be regarded as fully satisfactory, yet there are disappointing features in some sections. In Competition (A), many candidates have performed indifferently in regard to the costing of fabrics. The conditions demand that two of the specimens should be costed, and the errors recorded in this connection have been greater than usual. Some of the competitors have failed to provide details for cost of weaving, an omission which could not be overlooked in assessment. The Committee, at their final meeting for adjudication, reluctantly decided not to award a first prize, but to confer two equal second prizes. In addition to a third prize, however, five prizes of £5 each were awarded in place of four included in the prospectus. In woven furnishing fabrics, the exhibits with small ornamentation were the more successful both as to colour and pattern value. Shirtings were again mostly dealt with on usual lines of stripe formation and a little experiment in some other direction would be welcome. Several adjudicators agreed in recording a general improvement in good taste on the part of contributors to this competition.

In regard to Competition (B)—Novelty Folded Yarns—the display is excellent and shows an improvement in colour combination. The exhibits are more even in merit than those of the previous year and good command of fancy doubling technique is indicated in several instances. Great credit is due to competitors who have provided specimens illustrating the use of yarns.

In connection with Competition (C)—Special Woven Fabric for a Definite Purpose—the extent of the field for experiment which this section offers does not appear to be quite fully realised.

Decided advance is shown by exhibitors in Competition (D)—for Specimen of Woven Fabric submitted in connection with the Final Examination in Cotton Weaving (Section A or B) of the City and Guilds of London Institute.

In the main, competitors in Competition (E)—Knitted Fabrics—have relied on design and colour rather than stitch or formation of fabric. The fact that only one competitor essayed a lace type was disappointing. It was felt, too, that many competitors had mirrored recent styles of production rather than adventured into possibilities for the future. Over-ornamentation was obvious in one or two instances.

In the case of Competition (F)—Designs for Printed Fabrics—the fact that this is included for the first time is to be taken into account. The response has been fairly promising. The age limit of competitors (23 years) was probably too low and, for next year, the age is placed at 26 years or under. In the class for Designs for Furnishing Fabric, most of the competitors appear to have realised

the type of design required by the trade but they did not fully appreciate the importance of good colour combinations. Technique was reasonably good and in some cases the suitability of design to cloth was evidently fairly well considered."

Some indication of the interest now taken in these competitions may be secured by consideration of the following list which shows the widespread sources from which successful competitors entered.

Name of College, School, etc	Competition	Awards
Blackburn Municipal Technical College ...	B	Extra
Bradford Technical College ...	A	2nd
" " " " ...	B	1st and 2nd
" " " " ...	D	3rd
Burnley Municipal College ...	A	£5
" " " " ...	B	3rd
" " " " ...	D	2nd
Chorley Technical Institute ...	A	£5
Colne Evening Technical School ...	A	£5
Dewsbury School of Arts and Crafts ...	Fii	2nd
Hornsey School of Art ...	Fi	2nd
Huddersfield Technical College ...	C	Two 3rds
Keighley Technical College ...	D	1st
Leeds University—Textiles Department	A	£5
Leicester Colleges of Art and Technology	E	1st, 2nd, and 3rd
Manchester College of Technology ...	A	£5
" " " " ...	C	1st and 2nd
Manchester School of Art ...	Fi	1st
" " " " ...	Fii	1st
Nelson Municipal Technical School ...	A	2nd
Radcliffe Technical College ...	A	3rd

Prize Distribution

On Saturday, 2nd December, at 3 p.m., the prizes awarded by the Competitions Committee in accordance with the above-mentioned list were distributed by Miss E. R. Dust, lecturer in Textile Design at the College of Technology, Manchester.

In the unavoidable absence of the President, Sir William Clare Lees, the chair was taken by Mr. Frank Wright (Fellow), Chairman of the Council, who gave a brief outline of the activities of the Institute which included the Competitions, entries for which were displayed for inspection by all. He welcomed Miss Dust and said he thought her presence to present prizes was most appropriate. Not only that, but it was a small mark of the Institute's appreciation of her services in connection with the annual collection and issue of the Institute's Reference collection of Fabrics.

Miss Dust before handing the prizes to the winners said—I feel it a great honour to be asked to distribute the prizes this afternoon, because I consider these Textile Institute Competitions the most valuable and far-reaching competitions of their kind in the country for *students*, and, since the inclusion of the Knitting and the Fabric Printing Sections, also the most *complete* competitions in connection with the Design and Structure of Textiles. By their carefully planned conditions appeal is made to the experienced students of our Technical and Art Schools, many of whom are now ready and anxious for suitable positions in industry.

Perhaps one reason for my being exalted to the platform may be that I am considered a link between the Manchester College of Technology and the Art School through my long association with each.

This afternoon for my brief address I decided to have a *text*—the two words "Creative Design", this being suggested to me by an interesting advertisement a couple of weeks ago in the second column of the front page of the *Manchester Guardian*.

"Wanted a *Creative* Textile Designer for new styles in Cotton and Rayon Dress Goods, Furnishings, etc. Conversant with all processes from raw material to Woven fabrics. Ability proved before engagement—apply"

Although only a superman could fulfil these conditions absolutely, one feels respect for the advertiser in asking for the highest technical qualifications, along with what is far more rare, *Creative Ability*. But I honestly feel that some of the successful candidates in (A) Competition give evidence by their work (16 original woven cloths with ranges of colourings in respect of 8 of the samples submitted) that they have the ability, and have received the necessary training to tackle a comprehensive job such as this.

What do we understand by the word *Creation* in connection with Textiles? Certainly not "calling into existence out of nothing", but the act of investing with a *new character*. This *new character* which may be called "a happy inspiration", "a touch of the unexpected", and sometimes even "a stroke of genius", is more often than not the selling factor, and consequently of vital importance. This creative ability will first result from the personality and imaginative vision of the designer, and secondly from his or her sound knowledge of the materials and processes concerned in the production.

He must be able to create in terms of his material and conform to the dictates of fashion. This is of the utmost importance. Usually the most effective work is *not isolated*, but contributes to a general movement. Change in dwelling-house construction and furnishings, for instance, brings about new requirements in textile materials offering the greatest opportunity for creative effort in design. The designer for the ornamentation of textile fabrics must be *enterprising* and *daring*. If the enterprise is in harmony with other modern movements, so much the better.

If I were asked to state the most attractive qualities of the modern spirit in pattern design I should say *vitality*: the force so necessary in the successful marketing of goods. A spontaneous design will be a personal expression—nothing copied will have that quality. Think of the life and vitality shown in modern renderings of the most ancient of patterns—stripes, checks, and chevrons—they are rejuvenated and invested with the spirit of the times. No longer ancient, they are happy young things doing physical jerks. There must be hosts of other primitive patterns well worth reviving if we searched for them.

This essential thing, creative ability, is being almost frantically sought for in industry. Manufacturers in their efforts to produce novel and attractive goods are making an appeal to modern artists of distinction, whose visions they hope may be entirely new, to co-operate in industrial design. You probably know that 12 of Britain's leading artists have designed new chocolate boxes for a well-known firm. They include Nevinson, Connard, Rackham, Dulac, and notable women, Dod Proctor and Laura Knight, amongst others. This is the best thing that could have happened for designers—their status is at once raised by industrial art being given its proper position in the arts.

The same thing has come to pass in furnishing fabrics—professional painters and sculptors of the modern school are applying themselves to the practical needs of everyday life. In this group we find Duncan Grant depicting a modern cherub blowing out his cheeks in an effort to blow the clouds away; Cedric Morris the artist naturalist; Paul Nash; and Gregory Brown. These and many others are asked to work on their own individual lines, and the designs are afterwards made to conform to the processes involved in production. Many such designs are fresh in our minds from the recent Exhibition of Industrial Art from Dorland House in the Manchester Art Gallery.

The one thing that annoys me about this movement is the ridiculous way it has been advertised. "Famous artists come down to earth." "Genius touches furnishing fabrics," are examples of such unsuitable advertising, for in *my* opinion to-day the *artist* and *designer* are one. The textile designer may not be able to paint pictures, but he must be conversant with present-day art movement and foresee possible future developments.

Most of the styles in present-day fabrics have arisen from movements such as *Cubism* which has influenced every branch of industrial art enormously; *Impressionism* with its lovely broken colour akin to atmospheric vibration; *Futurism* with its mechanised aspect of modern life; and *Sur-realism*—pictures which bear relation to images fashioned by the sub-conscious mind—the artists working on the theory that mental vision holds ampler forms of beauty than the visible world.

J. E. Barlow in his B.B.C. booklet "Modern Art in the Changing World", says truly "Modern Art is practical. It no longer divides life into two parts with the practical on one side and the beautiful on the other". *Modern Art* accepts the machine—machine forms should not try to imitate hand forms. *Modern Art* gets rid of lumber—it is simple, bright, clean, and hard. *Modern Art* is another name for intelligent vision.

Now one word or two about research. I maintain that research work on the æsthetic side of applied art is *just* as important as research on the technical side. Natural ability is not enough—the earnest student must dig down and get at the root of the thing—he must search for material to invest with a new character, and in this respect the "Old Masters" in textile design are as well worth studying as the modern movements. It is no secret that at the Manchester College of Technology we are engaged in providing facilities to carry out research in design on both the technical and art side by devoting a pleasant room as a Design Studio and Library. It is in an ideal position adjoining the pattern weaving laboratory and the design lecture-room. Here students, whether designers, producers, or salesmen, will be able to study independently the styles of past and modern work both for home trade and foreign markets. Our priceless collection shows the progress of calico printing from 1792 and includes the Swaisland Collection of 100 books of fabrics; Claude Frere's 300 books of fabrics from 1893; 36 volumes of Indian fabrics; the Frank Warner and William Morris collection, together with a growing collection of current examples, including the "reference collections" issued annually by the Textile Institute.

To create something interesting and of lasting value involves power of repose and concentrated thought difficult to attain in these days of rush and nervous unrest. I trust that our Studio and Library at the Manchester College of Technology will for textile design become a miniature Courtauld Institute which, as we know, was recently founded by Mr. Samuel Courtauld in his old Georgian home in London, for, as it was described, contemplative study and research in the history and appreciation of art.

In this morning's paper I read with interest that a National Council is to be set up to deal with questions affecting the relations between Art and Industry. In reference to this, I will quote the words of Sir H. Llewellyn Smith, Chairman of the British Institute of Industrial Art, of *nine* years ago. "If one-tenth part of the energy, the intelligence, and the experience which is being concentrated in exploring the relations between industry and science had been devoted to the solution of the problems of relationship between industry and art, the position of some of our industries would be very different from that prevailing to-day. The industrial structure of the future **must** be built up on two solid foundations, one of these is science and the other art."

In conclusion I **am** sure that teachers and students present to-day at this Prize Distribution and Exhibition, must feel, as I do, greatly indebted to the Textile Institute for the great work it is doing for the promotion of the union between creative Art and Industry.

Miss Dust then presented the prizes.

Mr. Wright (Chairman) said he was sure everyone would like a few words from Mr. Crompton, the founder of the scheme. Many of those present would remember

the days when the facilities for technical education were very poor. Mr. Crompton had been associated with the inception of many of the schemes of development.

Mr. John Crompton (Fellow), Chairman of the Competitions Committee, said that it was indeed a pleasure for him to come to the Prize Distribution year after year. The time passed so quickly that there seemed only a few weeks between each event. His interest in the Scheme was as great as ever, and he thought there was ample justification for developing it. He was very pleased that, for the first time, a lady had been asked to distribute the prizes—one who had been closely connected with the art side of the industry for many years. Miss Dust had a wonderful knowledge of her subject, though she had not claimed the fact in her address. She had given valuable assistance to the Institute for a long time in accumulating the collection of fabrics sent as reference collections to the schools and colleges. She had said that the collection at the Manchester College of Technology was looked upon as being of great value. This value, said Mr. Crompton, increased with each year's addition, and he thought it was of importance to the student to go through the albums to see what progress and development had taken place. He was also glad to note that Mr. Runciman was prepared to appoint a Council to encourage art and industry in design and its application. Mr. Crompton pointed out that the work displayed was done by those still in training.

Mr. J. W. Kenyon (Fellow) said it was a great pleasure to him to be called upon to propose a vote of thanks to Miss Dust who had so ably performed the distribution ceremony.

Mr. R. Lord (Fellow) seconded. He thought in regard to the competitions that great credit should be given to the students. He pleaded for better recognition of costing.

Lancashire Section

Meeting at the Institute, Manchester, on Wednesday 15th November 1933, Mr. T. E. Mitchell presiding.

FABRICS FOR THE BOOT AND SHOE INDUSTRY

At this meeting Mr. W. Wilkinson (Fellow), Principal of the Blackburn Technical College, delivered a lecture on the above-named subject. He said—

We are all indirectly connected with this great industry, but unless one is intimately acquainted with it, very little idea can be formed of the wonderful organisation and technical skill involved in the manufacture of boots and shoes. During the past two years, I have visited many factories and watched with considerable interest the various operations performed by skilful hands and the most ingenious machines.

I have studied the system of technical education and have the greatest admiration for the work which is being done in this connection. Many of the schools are equipped with testing apparatus, not only for leather, but also for textiles, and the syllabus includes a study of the yarns and fabrics used in the industry.

Most of the large firms have their chemists and technologists, and some have specialists in form and design. It may be safely assumed that "efficiency" is the watchword of the Boot and Shoe industry, and no efforts will be spared on their part to co-operate with the textile industry in order to obtain the most suitable fabrics for their detailed requirements.

A considerable yardage of textile material is required annually for this industry and it is very essential for the textile manufacturer to understand exactly what

is required. In a general classification the fabrics may be divided into three groups—

- (1) The outside material of shoe uppers, which may be satin, crêpe, moiré, velvet, and various kinds of warp and weft pile textures and special materials with some kind of fabric as the base. Fabrics in this class are used in conjunction with some form of backing material to give the required strength for shoe-making purposes.
- (2) Fabric linings; usually drill or duck.
- (3) Other fabrics used for different parts of the boots and shoes and for special purposes, such as woven labels, tags, etc.

Class I

Some of the fabrics examined in this class are—

Black satins, with closely-set rayon warp and cotton weft, woven on 16 shafts working 2 as 1, to give 8 end satin.

Black plain fabric with rayon yarns.

White plain fabric with rayon yarns.

White satin, 10 end weave, with rayon warp and cotton weft, used mainly for covering the heels of shoes.

White satin, 8 end weave, all cotton yarn.

All these samples are interesting because they represent the kinds of fabrics that may be produced by the cotton manufacturer who is producing rayon and rayon mixture fabrics. This class may not be so important as regards the bulk trade for the Boot and Shoe industry, but if we consider the value of the goods, they represent a good proportion of the trade in textile materials. All grades of silk, rayon, and mixture fabrics in satin, plain, crêpe, velvet, and moiré structures are being used, but the possibility of new textures should not be overlooked. The shoe manufacturer is anxious to make new lines, introducing new textures, and this is a problem for the textile manufacturer.

Class II

Fabric linings, of course, constitute the greater portion of the trade, and it is intended to deal more with this section than the others, owing to the complaints frequently made by the users, and also to give some help to the textile technologist who may be considering the question of a more suitable fabric for this purpose.

There are two common defects in lining fabrics—(a) the tendency to bagginess and (b) splitting in the boot and shoe making processes. During recent years the use of combined linings has increased and this to some extent has reduced the defect of bagginess. The combined lining is formed by joining two suitable fabrics together by means of paste or rubber and so popular has the resulting fabric proved that there are manufacturers who make it their business to do this on a large scale for the trade.

The combined lining is as a rule lighter and stiffer and not much more expensive, but one would hesitate to say that this forms an ideal texture for the purpose. Attempts have been made to imitate the combined fabrics by ply textures in weaving, but the question of cost is one of the main reasons why they are not likely to be used in preference to single or combined fabrics.

It is suggested that combined lining fabrics are not without defects and the ordinary drill and duck lining textures are still used in large quantities. There is plenty of scope to improve these textures and a suitable single texture will have many advantages over the combined fabrics.

Particulars of typical examples of lining fabrics* are—

* Examples were exhibited by the Lecturer.

- A—35 in. Plain weave, 47 ends, 47 picks, warp 9-2's, weft 6-3's, warp crimp 8½%, weft crimp 11½%.
 Warp strength in cloth, 2 in. × 7 in., test 136½ lb.
 Weft strength in cloth, 2 in. × 7 in., test 203 lb.
 Unbleached stiffened duck used for men's, women's, and boys' linings and vamp linings.
- B—36 in. Plain weave, 49 ends, 47 picks, warp 2/16's, weft 2/17's, warp crimp 15-8%, weft crimp 8½%.
 Warp strength188½ lb. Weft strength225 lb.
 Unbleached duck, two-fold yarns, used for men's vamp linings.
- C—36 in. Plain weave, 54 ends per inch, 58 picks, warp 12-2's, weft 12-7's Tw., warp crimp 5%, weft crimp 12%.
 Warp strength116½ lb. Weft strength104½ lb.
 Unbleached stiffened duck used for women's vamp linings.
- D—32 in. White satin drill, 5 shafts, 105 × 56, warp 18-6's, weft 13-7's Tw., warp crimp 2½%, weft crimp 9%.
 Warp strength238½ lb. Weft strength141 lb.
 White Satin Drill used for men's and women's vamp linings.
- E—28 in. 4 Shaft Florentine, 97 × 49, warp 17-2's, weft 11-5's, warp crimp 5%, weft crimp 8%.
 Warp strength243 lb. Weft strength130 lb.
 White Florentine Drill used for women's vamp linings.
- F—34 in. Twill, 4 shaft, 55 × 113, warp 2/32's, weft 27-6's, warp crimp 1-1%, weft crimp 11½%.
 Warp strength116 lb. Weft strength67½ lb.
 Dyed Drill with raised back for women's vamp linings.
- G—32 in. 5 Shaft Satin, 104 × 59, warp 14-4's, weft 11-4's Tw., warp crimp 5%, weft crimp 10%.
 Warp strength246 lb. Weft strength168½ lb.
 Dyed Satin Drill used for men's bespoke and best vamp linings.
- H—28 in. Made by combined samples E and L, 3 × 1 with plain back.
 Warp strength281½ lb. Weft strength169½ lb.
 Used for women's vamp linings.
- J—28 in. Plain, raised on one side, 46 × 32, warp 21-2's, weft 5-2's, warp crimp 1%, weft crimp 10%.
 Warp strength82 lb. Weft strength53½ lb.
 Grey Swansdown used for women's interlining, stiffened and raised on one side.
 This type of fabric is used for plumping purposes when the leather is light.
- K—27 in. 2 × 2 Twill, four shaft, 60 × 43, warp 21, weft 7's, warp crimp 2½%, weft crimp 10%.
 Warp strength70½ lb. Weft strength74 lb.
 Grey Swansdown used for men's and women's interlining, stiffened and raised on one side.
- L—35 in. Plain, raised both sides, 39 × 31, warp 28's, weft 8's, warp crimp 3%, weft crimp 8½%.
 Warp strength48 lb. Weft strength16 lb.
 Cream Flannelette used for men's and women's interlinings, raised on both sides.
- M—37 in. Plain Duck, 44 ends, 35 picks per in.
 Warp strength64 lb. Weft strength158 lb.
 Typical tinted Duck for men's and women's side linings and interlinings in the manufacture of boots and shoes.

Particulars such as quality of yarns, turns per inch, single thread tests, yarn and cloth stretch before break, elasticity in the yarns and cloth have been omitted, but it is quite correct to state that not one of the nine lining fabrics has the characteristic features of an ideal texture for that purpose.

With the exception of the weft strength in Sample F and those used for interlinings, the breaking load per sq. in. is above what might be considered the safety factor, but it is found that most of these fabrics may split under certain conditions during the manufacture of the boots and shoes.

A short time ago, I discussed the question of an ideal lining fabric with an expert from the shoe industry and this is a summary of his remarks:—

- (1) The fabric should have a breaking strain each way of at least 40 lb. per inch.
- (2) A stretch each way, under a pull of 30 lb., of about 8 to 10%.
- (3) *An elasticity as great as possible.*
- (4) A bleached cloth, 50 square, from good yarns to give a full appearance.

The qualities which may be regarded as necessary for the ideal lining fabric are as follows—strength, stretch, elasticity, and appearance.

The *strength* required may come under two headings (a) strength required to withstand the strain during the processes of shoe-making, and (a) the strength to withstand the varying strains during the use of the fabric. The strength required for (a) is difficult to estimate, but one firm suggests that 30 lb. per sq. in. is a fair estimation. Therefore, a cloth which gives a breaking strain of 40 lb. per in. each way on a Goodbrand testing machine ought to be strong enough. There are many fabrics in general use with a less breaking strength which have not caused trouble, whilst many fabrics with considerably greater breaking strength have been known to snap during the making of the shoe. It is suggested that the strength of the fabric is not an important factor, since some of the strongest fabrics are just as difficult to work and cause as many complaints as some of the weakest. In actual practice, fabrics with a strength of 70 lb. per in. have been found to break, whilst fabrics with a strength of only 30 lb. and subjected to the same conditions have not snapped.

As regards the *stretch*, it is suggested that if the fabric is subjected to a strain or pull of 30 lb. and the stretch is 8 to 10% in each direction, this gives satisfactory working conditions. Fabrics with less stretch are difficult to handle and if there is an excess of this amount there is always a tendency to bagginess. One very important point to note is that the stretch should be about equal in both directions and since most fabrics are bleached, the stretch is often reduced lengthwise.

Grey, plain, or duck fabrics are most satisfactory so far as stretch is concerned. The degree of *elasticity* of a lining fabric decides its suitability, and this property should receive the most careful consideration. Many fabrics have only a small amount in one direction, and even less in the other direction, whilst some have a reasonable amount length-way and practically none across the piece.

In bleached fabrics the elasticity is reduced in length of piece as compared with its grey state. In grey fabrics of plain structure woven with folded yarns the elasticity (which is very difficult to estimate) is greatest and if the yarns are of good quality and have sufficient turns per inch it has been found that the elastic nature of the fabric is about 60 to 70%. With single yarns and normal turns per in. in the yarns the elasticity is not more than 30 to 40%.

The *appearance* of a lining fabric is important and the smooth warp face of a good drill or satin has been in favour. The fabrics are usually bleached, but both grey and tinted fabrics are used. The matt surface of a duck fabric gives a good appearance and this type of fabric has many other favourable characteristic features.

It is suggested that the lines for the investigator to work upon in connection with the problem of finding the ideal lining fabric are (a) to determine what amount of elasticity can be obtained in the finished fabric when ordinary commercial yarns are used, (b) the most suitable texture—yarns to use, ends and picks per in., turns per in. in yarns, weave and kind of finish to give to the fabric—and (c) how far it is possible to introduce special yarns in order to increase the elasticity without impairing the appearance and wearing properties of the fabric.

For some time past we have devoted attention to the possibility of using *Lastex* yarn for lining fabrics*. The loom used, is one specially designed for experimental purposes and weaves in single picks working with alternate picking from each end of the loom; the loom speed for the purpose of testing the "Lastex" yarn was reduced to 140 picks per minute. The warp is 2/80's, 132 ends per inch, 3/88's reed. 8's weft has been used in conjunction with 100's "Lastex" yarn. The width on reed is 33½ in. and the picks per in. were varied according to requirements.

For most of the fabrics, two ends work as one, giving a warp count equal to 19's–20's. All the strength, stretch, and elasticity tests have been made weft way and no account has been taken of the warp.

*A number of samples were shown.

Fabrics of a given weave have first been woven with cotton weft, and then the cotton has been taken out and "Lastex" yarn substituted in varying proportions up to 50%, that is, three shuttles weaving cotton and three weaving "Lastex" yarn, next four shuttles were filled with cotton yarn and 2 with "Lastex" yarn and afterwards 5 cotton and 1 "Lastex" yarn. Thus giving the proportions of $\frac{1}{2}$, $\frac{1}{3}$, and $\frac{1}{4}$ of special yarn.

Further samples are to be woven, giving smaller quantities to complete the tests when the above fabrics have been carefully examined in their finished state. The tests of the grey samples show a decided drop in the strength of the fabric and this follows the proportion of "Lastex" yarn to cotton.

The weft strength in a sample woven with 8's cotton weft and 58 picks per in. is 167 $\frac{1}{2}$ lb. and in a sample woven immediately afterwards with all particulars the same except that 50% of the weft was "Lastex" yarn a strength of 75 lb. was recorded.

Observations made during the cloth strength test with 50% "Lastex" yarn were as follows. Immediately the machine was set in motion the driving grip extends the cloth under a very light load. After a short time the cotton in the fabric begins to take the load and the indicator moves rapidly over the scale. When the load has reached the breaking point of the cotton the cotton breaks, but the elastic is still present and intact. The indicator moves backwards, rapid extension takes place with the elastic and when the limit is reached the elastic strands break down.

The weft strength in a sample woven with 8's cotton weft and "Lastex" yarn in a thicker grade, all other particulars being the same as the one which gave a weft strength of 75 lb., had a strength in the grey state of 79 lb., and after bleaching was 82 lb. In another sample the grey and bleached strengths were 108 and 100 lb. respectively. The weave of the fabric was different and this was responsible for the difference in strength, but it is difficult to explain why the strength of the bleached samples was above in one example and below in the other. Many tests were made and with the two structures the same differences were recorded.

The first series of experiments made were on the lines of special types of fabrics structure, and it was thought that backed fabrics with a cotton face to give hard wearing properties and a back of "Lastex" yarn in a plain weave would provide a suitable structure. A range of 20 fabrics was produced on these lines and some very interesting results were obtained, but the tendency to curl was so pronounced that the fabric could not be handled in the finishing processes. It is suggested that ply or compound textures with all the "Lastex" yarn on either face or back is not practicable and if such weaves are desired the "Lastex" yarn must be between the two cloths in compound textures or equally distributed on face and back when backed fabrics are produced.

The next experiments were devoted to standard structures such as plain, twill, satin, and simple weaves designed to give maximum extensibility in both directions. The samples were woven in four grades and each set had (a) all cotton, (b) equal cotton and "Lastex" weft, (c) two-thirds cotton and one-third "Lastex" and (d) five-sixths cotton and one-sixth "Lastex".

It will be found that most of the grey samples in the grey state, give very little evidence of containing any special yarn, but immediately the fabric is placed in water a contraction of about 4 in. in width takes place and most of this contraction remains throughout the bleaching process and also the fabric remains flat.

The amount of elasticity in a fabric containing "Lastex" yarn depends upon many factors and according to the percentage of this material present, it is found that when the "Lastex" controls the fabric, many unreliable features exist, but when the major portion of the fabric controls the "Lastex", and the "Lastex" only, assists so far as the elasticity is concerned, then the width, length, and appearance of the fabric can be controlled and the results may be said to be reliable. For this reason it is suggested that if additional elasticity is given to

lining fabrics by the introduction of "Lastex" yarn the percentage should not be more than 10% of either warp or weft and that both warp and weft should be treated with regard to making the elasticity in the finished fabric as near equal as is possible.

Before leaving the question of elasticity, a few remarks regarding the yarns used in conjunction with "Lastex" yarn may be interesting. The 8's weft yarn used during the experiments did not give the results we expected and this was largely due to the quality and the number of turns per inch. The number of 4 to 4.25 turns per inch in the weft used was 12. If a twist constant of 4 to 4.25 and a good quality of cotton had been used, this would have given a greater percentage of elasticity and a stronger fabric.

If the investigator rules out the use of special yarns as a means to produce the required amount of elasticity, he will be required to make a careful study of (a) the structure of the fabric; (b) the quality of cotton and twist of yarn; the use of mixture yarns; and also yarns specially constructed to give elasticity without impairing the surface of the fabric which must for obvious reasons be fairly smooth. There is plenty of scope for investigation and one does not find much published matter dealing with this type of fabric. It may be true that firms have found fabrics which suit their requirements, but I have yet to find a pair of boots or shoes which, after a reasonable amount of wear has a lining fabric without a trace of bagginess.

The ideal lining fabric will materially assist in keeping the shoe in shape particularly in the lighter production and there appears to be an increased demand for this type of footwear. The canvas boot and shoe fabrics are made in various qualities and are given in particulars—

Shoe Duck	...	54/100	40 × 32	2/12's	3/14's.
Shoe Duck	...	96/50	52 × 34	2/14's	2/18's.

It is suggested that if these fabrics are made with the maximum elasticity with the two or three-fold yarns, or with special "Lastex" yarns, in a correct proportion to give more elasticity than can be obtained with ordinary yarns, the fabric would be durable in use and retain its shape for a greater length of time.

The fabrics for the outer covering of shoes and slippers are in a class apart from those considered to be the object of this lecture. The slipper trade consumes large quantities of fabric and many are very interesting structures. Both heavy and light textures are in demand. As in most industries, many changes have to be made to suit the taste of the customers and the fabrics that were in demand a few years ago are replaced with different structures and modern designs.

In conclusion, it is suggested that the requirements of the Boot and Shoe industry are too important to be ignored by the Textile manufacturer and they should be investigated with the object of supplying better fabrics for the purpose of linings and interlinings and also those for the outsides of shoes. It is often found that the fabrics that are being used have been selected because they were the nearest to their requirements. By attempting to understand these requirements and by a closer co-operation between the two industries, it should be quite easy to create fabrics that are more exactly suited to their uses.

DISCUSSION

Mr. T. E. Mitchell (Chairman) said that he had been very interested in Mr. Wilkinson's subject. It seemed to him that the chief difficulty was in lasting and that the stronger the fabric used the poorer the result. Shoes had to be made at a price and the maker knew that it was useless to produce something which was too expensive. The maker was also extremely critical as to the kind of material used and, said Mr. Mitchell, it was up to the manufacturer to see that the shoe manufacturer received a fabric suitable and satisfactory for the job.

Mr. Frank Wright referred to "Lastex" and asked if it was vulcanised.

Mr. Wilkinson replied that it was.

Mr. Wilkinson stated that he had tried to rot "Lastex" by putting it into very strong bleaching liquor. After a week's immersion it appeared to be as strong as before. The cloth strength was about the same.

The lecturer was asked if fabric was stretched when lasted.

Mr. H. Salt, H.M.I., replied to the question and gave a general outline of the formation of the boot and explained that the leather took the greater part of the strain. Apart from this the greatest strain experienced by the lining fabric was at the toe.

Another questioner asked if a special fabric was used for the work. Mr. Wilkinson replied that no special fabric was manufactured for the purpose.

Mr. W. Kershaw asked if the shoe industry was not a field for the use of bias fabrics.

Mr. Wilkinson replied that quite a lot of such fabrics had been used. Some makers said that the use of combined fabrics eliminated splitting, but others did not think so.

Mr. S. Taylor said he gathered that the fabric required had to be of equal strength both warp and weft way. He believed that a lot were woven with single warp and weft, the warp being heavily sized. He wondered whether the fabric depended entirely on a suitable finish.

Mr. Wilkinson said he had not considered this aspect of the question. The whole subject was full of difficult problems. Finishing might modify present ideas. It might be wise to explore the question of greater elasticity.

Answering a question as to the class of yarns from which the fabrics were made, Mr. Wilkinson said he understood ordinary commercial yarns were used. In many instances the manufacturer was not aware that the fabrics were going to the boot and shoe industry.

Mr. Salt answered a question relating to the price of smallwares for the boot and shoe industry and stated that he had no prices available. He and Mr. Wilkinson had confined themselves to the fabric side of the industry.

On the motion of Mr. Frank Wright, seconded by Mr. Fletcher Chadwick, a hearty vote of thanks was accorded to Mr. Wilkinson and Mr. Salt.

Yorkshire Section

Diplomas of the Institute

The Yorkshire Section of the Institute promoted a meeting held at the Technical College, Keighley, on the evening of the 27th November, when explanatory statements were contributed in regard to the Diplomas of the Institute—Associateship and Fellowship. Mr. T. H. Robinson, Chairman of the Section Committee, presided, and the Mayor of Keighley (Mr. Ernest Whalley) attended and welcomed the Institute representatives. The Mayor expressed warm appreciation of the efforts of the Institute to raise the status of the textile technologist. He said they were proud of their technical college and he was glad that some of their teachers and students had succeeded in acquiring Institute qualifications, whilst students had figured among the prize-winners in recent years in connection with the Institute's competitions in relation to design and structure of fabrics.

Mr. Henry Binns (Bradford) spoke on the value of Institute qualifications to the industry; Dr. J. B. Speakman (Leeds) contributed an address on the Examination Syllabus of the Institute; and Mr. J. D. Athey (General Secretary) dealt with regulations and procedure in relation to applications.

There was a good attendance of students, and Mr. Healey, Principal of the College, spoke in warm appreciation of the Institute movement.

At Huddersfield Technical College, on the evening of the 11th December, a similar meeting was held, when Mr. T. H. Robinson again presided. Mr. F. W. Barwick, Chairman of the Selection Committee of the Institute, addressed the gathering, referring to the syllabus of the Institute examination and also dealing with the requirements of the industry as to the services of the trained textile

technologist. The growth of the use of textile materials for industrial purposes had brought about demands for special materials manufactured to exacting specifications involving expert control in production.

Mr. George Garnett, Past-President of the Institute, spoke on the value of the Institute qualifications to the textile industry, and advised students to pursue the study of problems long after the conclusion of the usual courses of study at colleges and schools. Membership of the Institute would help them to keep abreast of progressive changes in practice.

Mr. J. D. Athey (General Secretary) dealt with the Regulations governing awards of the Institute diplomas and procedure in relation to applications, more particularly applications for the Associateship.

Many questions were asked, and, in reply to criticism as to the great extent of ground to be covered in the examination in General Textile Technology, it was pointed out that printed copies of past examinations were available, and the requirements could be best estimated by perusal of these records.

NOTES AND NOTICES

Industrial Designs—Competitions

The Secretary of the Royal Society of Arts, in a report on this year's competitions in relation to industrial designs, states that, in consequence of the heavy costs incurred by the Society in organising these competitions, the Council have, in spite of their success as shown by the increasing number of entries during the past ten years, very reluctantly been compelled to suspend the arrangements for future competitions of this description until help from other sources and the necessary funds are available. It will not therefore be possible to hold a competition in 1934. Ten competitions for designs for Architectural Decoration, Textiles, Furniture, Pottery and Glass, Book Production, Posters and Showcards, Silverware, and Leatherwork have been held since 1924, and Travelling Scholarships and Prizes of the total value of £11,500 have been awarded to young students, designers, and craftsmen. The Secretary of the Royal Society of Arts also reports that the competitions have proved that there is no lack of creative talent among the younger generation and they have been the means of discovery and rewarding promising designers and craftsmen whose work would otherwise have been unknown.

The Textile Institute continues to maintain its programme of competitions in regard to design and structure of woven fabrics (under the Crompton Memorial Fund Scheme) whilst other prizes are offered for textile design and also for fancy yarns. The prizes awarded by the Institute, however, are on a modest scale and there is a growing feeling that the real importance of such competitions is not to be measured by the amount of money distributed as prizes. The Institute has proceeded cautiously, yet courageously, in regard to its commitments on the score of prize-money. The prospectus for next year's competitions, now available, indicates modification in the prize-money offered, though reduction is effected in only one section. This Institute has long recognised that casual and varying financial support for enterprises of this kind offers no real substitute for donations invested so as to yield a more or less permanent income for the purpose.

Lancashire Section's Social Event

Some years ago, the Lancashire Section Committee promoted several social gatherings, usually in the form of a concert or whist drive. A recent request for the inclusion of a social gathering in the programme for the current session resulted in a decision to promote a dinner-dance, which will take place at the rooms of the Manchester Limited, Royal Exchange Buildings, Manchester, on the evening of Saturday, 13th January. In arriving at their decision, the Committee frankly agreed to follow the custom of several kindred organisations

in the matter of social events. Similar gatherings in connection with other bodies have proved distinctly successful. It is encouraging to note that even before the issue of notices of the event, requests have been received for reservation of tickets. In the preliminary announcement, it was stated that the charge for tickets would be 7s. 6d. each. It has now been arranged, however, that whereas the cost of individual tickets remains at this figure, the charge for double tickets shall be 12s. 6d. By this means, the Committee hope to get a really good attendance of members and ladies. In addition to the dinner and the dance, it is hoped to provide accommodation for bridge-playing as alternative to dancing. The Committee would gladly welcome attendance of Members attached to any other Section of the Institute.

The Clothworkers' Company

In connection with the London Section of the Institute, an interesting meeting is announced to take place on the evening of the 21st March next. Mr P. M. Evans, C.B.E., Clerk of the Clothworkers' Company for a great many years, has consented to contribute a lecture on the origin and history of the Company. Excellent support of various branches of our activities has been conceded to the Institute by the distinguished Company named, whilst the London Section has been greatly privileged by the generous arrangement under which many meetings are held in the Clothworkers' Hall. Having regard to this sympathetic support over many years past, the London Section Committee has asked the Council of the Institute to take a special interest in the event fixed for 21st March next. At the November meeting, the Council most readily gave their assurance of the warmest interest in the fixture, and several expressions of desire to attend were immediately forthcoming from individual members. Further announcement will be made as to the event and, meantime, Members generally are asked to make note of the date.

Institute Premises

The Headquarters premises of the Institute, at Manchester, have proved extremely convenient in many respects. The chief drawback experienced in recent years has been the lack of available accommodation for an increase of storage space. In view of the fact that the lease of the premises expires at the end of next year, a Sub-committee of the Finance and General Purposes Committee has carefully reviewed the situation and considered alternatives. The question of renewal of the lease has been under discussion with representatives of the owners, the Manchester Geographical Building Company Limited, and an agreed basis for renewal of the lease arrived at. The matter was brought before Council at the December meeting, and it is fully expected that occupation will continue for a further term. In the matter of storage accommodation, arrangements are contemplated which, it is anticipated, will meet requirements for at least several years to come. The scheme involves the re-housing of the contents of the existing stock-room.

Federation of Textile Societies

The delegates to the next Annual Meeting and Conference of this Federation will be the guests, for the occasion, of the Halifax Textile Society. The event has been fixed to take place at Halifax on Saturday, 24th March next. Meanwhile, on the afternoon of Saturday, 27th January next, the Committee of Management of the Federation (Chairman, Mr W. Kershaw) will meet at the Textile Institute, Manchester, for the purpose of concluding arrangements. The annual assembly of the Federation is movable and several textile centres have been visited—Oldham on the last occasion (1933). The inviting Society, in return, is asked to nominate a representative to be elected as President at the subsequent annual meeting. Bradford was visited in 1932, and Mr E. M. Roberts, the existing President, was afterwards nominated by the Bradford Textile Society. The Oldham Technical Association and Old Students Union has already nominated Mr G. H. Thompson, F.T.I. for election at the 1934 meeting.

Scientific Management—International Congress

Considerable progress is being made with the organisation of the Sixth International Congress for Scientific Management which is to be held in London from 15th to 18th July in 1935. A strong Council which includes representatives of Societies connected with some phase of scientific management has been formed, the Textile Institute being represented by Mr. Frank Nasmith.

H.R.H. the Prince of Wales is Patron of the Conference, and Government support has been promised. The Chairman of the Conference is Sir George Beharrell, D.S.O., Managing Director of Dunlops. The Chairman of the various Committees are Dr. E. F. Armstrong, F.R.S. (Organisation), Sir Henry Fowler, K.B.E. (Technical), and Mr. G. R. Freeman, F.C.A. (Finance). Mr. H. Ward, late General Secretary of the National Institute of Industrial Psychology, has been appointed Secretary.

It is hoped that the Congress will demonstrate that British industry and British technicians are fully alive to the importance of scientific principles in management, and still stimulate the national movement in this direction. Amongst the questions which will be discussed are—

- (a) Concrete examples of the Application of Scientific Management to Distribution Problems in Manufacturing, Wholesaling, and Retailing.
- (b) Methods of Controlling Production.
- (c) Methods of Selection, Education, and Training of Personnel suitable for high administrative positions.
- (d) What are the correct methods of inculcating Modern Management Principles and Practices in large-scale, medium, and small undertakings? What is the rôle of Trade or other associations in this field?

Textile Institute Diplomas

Elections to Fellowship and Associateship have been completed as follows since the appearance of the previous list (November issue of this *Journal*)—

FELLOWSHIP

SHARP, Benjamin Ralph Downs (Bradford).

YEWDALL, Alexander (Leeds).

ASSOCIATESHIP

BRONNERT, David Henry (Manchester).

Institute Membership

At the December meeting of the Council, the following were elected to Membership of the Institute—*Ordinary*—J. Cuito-Canals, Avda. Republica Argentina 259, 4^{art}, 1^a, Barcelona, Spain (Dyeworks Manager); Jack Kenyon, The Knoll, Byrons Lane, Macclesfield (Silk Manufacturer); Wm. Ogilvy, 286 Strathmartine Road, Dundee (Factory Manager, Baxter Bros. & Co. Ltd.); Dr. W. Reiners, 48 Rheydterstrasse, M. Gladbach, Germany (Textile Machinery Manufacturer); R. Sadasivan, 7 Crescent Road, Highground, Bangalore, S. India; H. Sharples, 29 Co-operative Street, Bamber Bridge, near Preston (Carder, Cotton Spinning); T. Sun, 54 Woodsley Road, Leeds (Student); A. Thompson, "Dolbury", Lime Grove, Chaddesden, Derby (Supervisor, Warping, and Sizing); S. A. Welch, B.Sc. (Lond.), British Celanese Ltd., 22 Hanover Square, London W1 (General Manager, Knitted Fabric and Made-up Goods Depts.); C. Blinkhorn, 26 Ephraim Street, Preston; A. R. Olpin, Kendall Mills, Paw Creek, N.C., U.S.A. (Research Work in Textiles); J. H. Poulton, 8 Ethel Street, Thornbury N. 17, Australia (Director, Keith Jacobs & Co.); Dr Walter Kling, c/o H. Th. Bohme A.G., Neefe str. 123, Chemnitz, Germany (Chemist in Scientific Laboratory); B. P. Ridge, Hilltop House, Hunts Lane, Latchford W., Warrington (Research Chemist). *Junior*—Kenneth T. Barrett, 12 Oxford Street, Keighley (Apprentice, Worsted Spinning and Twisting Overlooker); C. J. Breakell, Farringdon Park Lodge, New Hall Lane,

Preston (Salesman's Assistant, Manufacturer's Office); J. M. Furness, Brooklyn, Farington, near Preston (Cotton Spinner's Clerk); F. J. Ireland, 100 Miller Road, Preston (Designer and Particulars Clerk, Burrows Ltd.); Eugene Y. T. Kan, 12 Cromer Terrace, Leeds 2 (Student); R. K. Kandaswamy, 10 Delacourt Road, Fallowfield, Manchester (Student); A. Nelson, 8 Houghton Street, Bradford Road, Brighouse, Yorkshire (Service Clerk, B.D.A.); R. Venkataswamy, College of Technology, Manchester (Student).

REVIEWS

Final Report on the Fourth Census of Production (1930). Published by H.M. Stationery Office. (Price 7s. net.)

During the year 1932 a series of supplements to the *Board of Trade Journal* summarised the principal results of the fourth census of production. The present volume is the first of a series of five "final" reports, amending and adjusting the provisional returns in the earlier series, and adding information about wages, the volume of production, and the size and distribution of businesses.

The value of data relating to the condition of the textile trades, the clothing trades, and the leather trades in the year 1930, may be doubted by many people after an interval of three years. Since this census was taken our currency has gone off the gold standard, the full force of a depression in trade has been registered, and we have developed the regulation of trade by tariff and quota. It would be unwise, however, to discount the value of the census because these changes have occurred. In its pages we may read the effect of international uncertainty on the course of business between 1924 and 1930. When the next census is taken, this present record will give us the measure of the impact on our economic system of the currency and tariff changes initiated in 1931.

In the general report on the textile trades it is stated that the volume of production of all textile products in Great Britain was lower in 1930 than in 1924 by nearly one-fifth. Reference to the separate industrial records shows, however, that this "omnibus" presentation of the position conceals the extremes of a decline of 40% in cotton manufactures and an increase of 145% in the output of silk and artificial silk.

Particulars of the drop in the number of establishments in the textile industries reveal a less pronounced decline than widespread talk about bankruptcies and rationalisation had led one to expect. It is interesting, also, to find that firms employing less than 300 persons represented in 1930 about half the production and employment in the industries. Firms employing less than 100 persons, and those employing 1,000 and over, were approximately equal in importance. In the woollen and worsted industry about one-half of the people employed were in firms of 300 or more, but such firms covered only 9% of the returns; a clear indication of the frequency with which the small firm still occurs in textile manufacture.

Returns of net output per head will add new zest to the debate about the efficiency of large and small units, for we are told that the net output, both for the textile trades as a whole and when the cotton trade is excluded, "was highest in the group containing the largest firms and next highest for firms employing from 25-49 persons".

The detailed reports on the hosiery and the silk and artificial silk industries present a record of expanding employment and production which stands in sharp contrast to the contraction of output and employment in the cotton and wool textile industries. This compels us to consider whether the balance of textile activity in this country is not steadily changing. And the question is made more pointed by the tables in this volume giving the relation between production, exports, retained imports, and home consumption. Both the cotton and wool industries have lost heavily in the export trade, and it is plain that in each case the home market is unlikely to afford adequate compensation for that loss. If a substantial export trade cannot be recovered, what then? For the time being we must take consolation from the fact that the share of the home market held by British products has been well maintained, and in a number of cases is over the 90% mark.

Both employers and operatives will turn with interest to the table showing the relation between wages and net output. In only three trades—hosiery, lace, and elastic webbing—did wages form a smaller proportion of net output in 1930 than in 1924. In the cotton trade the proportion was 70·6% compared with 54·5 in 1924; in wool textiles 52% compared with 50·1%; in silk and artificial silk 57·2% in 1930, compared with 31·4% in 1924.

Tables are the essence of a census, and in this instance the accompanying text is concise and instructive. If we can remember that every figure represents work done, the volume becomes an absorbing record of industrial progress. As a work of reference it is invaluable to every textile manufacturer and merchant, because from these pages only can he gain a full view of the trends in textile industry and trade.

A.N.S.

Colorimetry: Its Applications in Analytical and Chemical Practice. By Dr. Hugo Freund (translated by F. Bamford, B.Sc.). Published by the Author. Sold by E. Leitz & Co., London, 1932 (8vo., 255 pp., price 10s.).

Great advances have been made in analytical practice in recent years by the discovery of methods for the determination of small quantities of chemical substances in which the measurement of coloured solutions is the critical operation. These methods often employ highly specialised reagents that behave in some specific manner towards a single reactant or small group of related substances. A book dealing with these "colorimetric methods" is therefore to be welcomed and the author, translator, and printer are to be congratulated on producing a concise and neat volume. Unfortunately, they have provided very little for textile workers, except a chapter on the measurement of *pH* values and this is diminished in value by the fact that the methods described require a special colorimeter, which is by no means in common use. The best section is that dealing with medicine.

J.C.W.

PUBLICATIONS RECEIVED AND ADDED TO THE INSTITUTE LIBRARY

Auxiliary Products: Imperial Chemical Industries Ltd. (Dyestuffs Group).

A loose-leaf cover containing five guide sheets labelled—Wetting Agents; Detergents; Emulsifying Agents; Miscellaneous Products; and Useful Information. Pamphlets are included describing "The Uses of Wetting Agents"; "Permal W"; "Turkey Red Oil PO"; "Lissapol A"; and "Permal NF". The whole is a very attractive and useful addition to the Finisher's Library.

Jute: Annual 1933. Published by the British-Continental Press Ltd., of Fleet Street, London. (Price 12s. 6d.)

This is the third annual issued on jute. It contains new chapters in the editorial section, such as "New Uses for Jute"; "Proofing of Jute Cloth"; and "The Future of Linoleum". In addition, there has been added a comprehensive Directory of the Jute World, which definitely adds to the value of the work.

The Yorkshire Textile Industry 1933-34. Published by John Worrall Ltd., Oldham. (260 Pages and Indexes. 15s. post free.)

The 49th edition of this Directory has recently been issued and its contents have been thoroughly revised. Without such a thorough revision the work would not be worthy of annual issue. As it is these "Worrall" Directories are among those books of reference most frequently taken from the shelves.

City and Guilds of London Institute. Report of the Department of Technology for the Session October 1932—September 1933. (1s. net.)

This booklet gives particulars of the examinations held under the auspices of the Institute during the 1932-33 session. The number of centres for examination, the numbers of candidates, and the results are given, together with information as to the Advisory Committees set up by the Institute, its acting examiners, and winners of special prizes, scholarships, and exhibitions. Details of examinations in textiles are set out separately.

Skinner's Cotton Trade Directory of the World 1933-34. Published by Thomas Skinner Ltd., London and Manchester. (Price 20s. net.)

This is the eleventh issue of a well-known Directory which has been revised as to detail and improved by the inclusion of a Knit Goods Manufacturers' section. The general index of all firms included is a very useful feature of this publication.

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THE JOURNAL
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TRANSACTIONS AND INDEX

THE JOURNAL OF THE TEXTILE INSTITUTE TRANSACTIONS

1—THE ESTIMATION OF DAMAGE ON CHLORINATED KNITTED WOOL FABRICS

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INTRODUCTION

The purpose of the work described in this paper has been to examine the physical and chemical methods available for the estimation of damaged wool fabrics and to attempt a correlation of the two branches. The need for a new standard has become evident during prolonged researches into the action of chlorine on knitted wool fabrics. In the course of this work, it became necessary to measure the degree of damage sustained by a large number of wool samples during treatment with chlorine to produce an "unshrinkable finish."

PHYSICAL METHODS

The only physical means at present available is microscopic examination; with this is usually combined some form of sampling and counting, so as to produce a figure to express a "per cent damage." This is the method generally used in the hosiery trade in order to form an idea of the potential resistance to wear of treated garments. The sampling may be conveniently done by extracting short lengths of yarn from different parts of the fabric: it is advisable to work diagonally across the fabric to avoid taking samples from the same knitted course. Each yarn sample is carefully untwisted to open out the fibres, mounted on a slide using a drop of water, and examined under the microscope. The first five fibres seen on each slide are estimated for damage; by taking twenty such slides a total of one hundred different fibres from the sample will be assessed. It is necessary to untwist the yarn sections thoroughly to ensure even mixings of the fibres from the outside and inside of the same yarn, since the latter invariably show much less damage than the former.

There are two systems in use for assessing the degree of damage. By the first method an undamaged fibre is returned as zero and a damaged fibre as a unit. By examining one hundred fibres and taking the total, a figure is obtained which expresses the "per cent damage." The maximum figure allowable on this system is 5–10% according to the class of wool. The chief difficulty encountered in this method is the placing of those fibres which show a certain amount of damage, while they still retain some of their original scale structure. Here the personal equation of the observer is bound to show the weakness of this system. A difference of judgment between two observers may mean a difference of three units in the total. Since the total will probably be five, the difference can be 60 per cent. This difficulty is largely minimised on the second system of counting.* Three groups of fibres are recognised: undamaged fibres are counted as zero, partly damaged fibres as a half unit

* The author's cordial thanks are due to A. E. Garrett, B.Sc., of the Jaeger Co., for the details of this method.

and badly or totally damaged fibres each as one unit. The advantages of this system are evident. The error caused by placing a fibre in the wrong group is only half a unit and the partly damaged fibres fall more naturally into their own group. The maximum figure allowable on this system is 35%–40%, corresponding to about 6% on the first method. By placing three fibres in the wrong group, the maximum error is 4% of the total. In most cases a good result can be obtained by counting fifty fibres from ten slides. Table I shows a typical set of results from a chlorinated wool fabric. Figures are included to show the mean of each slide and also the progressive mean as the result of each slide is added.

Table I

No. of slide ...	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	$\frac{1}{2}$	0	$\frac{1}{2}$	$\frac{1}{2}$	0	$\frac{1}{2}$	1	1	0	0	1	1	1	1	0	$\frac{1}{2}$	1	$\frac{1}{2}$	0	0
	$\frac{1}{2}$	1	0	$\frac{1}{2}$	1	0	$\frac{1}{2}$	0	1	$\frac{1}{2}$	0	0	$\frac{1}{2}$	$\frac{1}{2}$	0	0	1	$\frac{1}{2}$	1	0
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	0	$\frac{1}{2}$	0	1	0	$\frac{1}{2}$	$\frac{1}{2}$	0	$\frac{1}{2}$	0	$\frac{1}{2}$	1	0	0	1	0
	$\frac{1}{2}$	0	$\frac{1}{2}$	$\frac{1}{2}$	0	0	0	$\frac{1}{2}$	1	1	1	0	0	0	0	1	0	0	$\frac{1}{2}$	1
	$\frac{1}{2}$	0	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	0	1	0	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	0	$\frac{1}{2}$	$\frac{1}{2}$	0	0	1	$\frac{1}{2}$	$\frac{1}{2}$	0
Slide totals ...	3	1	2	2	1	1	2	2	2	2	2	2	2	2	1	3	3	1	3	1
Slide per cents.	60	30	40	50	20	30	50	50	50	50	40	40	50	40	20	70	60	30	60	20
Progressive mean ...	60	45	43.3	45	40	38.7	40	41.2	42.2	43	42.7	42.5	43.1	42.9	41.3	43.1	44.1	43.3	44.2	43

These results are plotted on the accompanying graph: it will readily be seen that the progressive mean, which is represented by the broken line, soon settles down to a nearly steady value.

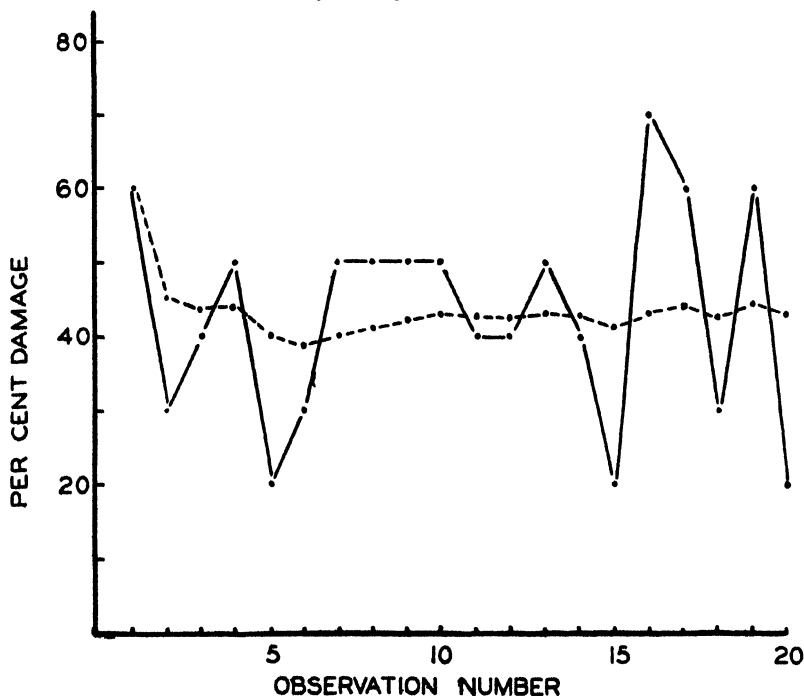


FIG. 1

After the first ten readings the oscillations of the curve become very small. It is possible, in practice, to get sufficiently accurate results by counting fifty fibres from ten slides.

CHEMICAL METHODS

The first method tried was an application of the staining aid used by Burgess and Rimington¹ (1929), the treatment of the wool following the technique described by von Brunswik². This is a development of the well-known "Pauly test" introduced by Pauly and Binz. Damaged fibres are stained a yellow to red brown by this reagent, the shade depending in depth on the degree of damage sustained previously by the fibres. It was hoped that this treatment would render microscopic classification more certain and more rapid. The difficulty encountered lies in the extreme sensitivity of this staining test; all the fibres are damaged to some extent and exhibit a rather deep colouration. The difference in shade was small and masked by this deep staining. The trouble was obviated in some degree by increasing the ratio of cloth to reagent, so producing a lighter stain throughout the fibres. The results obtained were an improvement on the original but still did not give certain results in the case of the doubtful fibres.

Attention was then turned to the development of the above method published by Rimington³ (1930). A method for quantitative estimation of wool damage was described, together with a modification of technique suitable for works practice. The use of the microscope is avoided by dissolving the stained wool in caustic soda to give a coloured solution which may be matched against a standard solution of a dyestuff. The conditions specified by Rimington were followed exactly in this work, except for modifications in the colour matching, necessitated by the high degree of damage. The details of the method are reproduced here—

Solutions Required

Sodium Sulphanilate ...	10%	Sodium Nitrite ...	8%
Sodium Carbonate ...	9%	Sodium Hydroxide ...	10%
New Acid Brown S* ...	0.1%	Concentrated Hydrochloric Acid	

Method of Application

Wet the wool sample thoroughly by standing in a tube with 15 c.c. of the sodium carbonate solution. Mix together 10 c.c. of the sodium sulphanilate solution and 5 c.c. of the sodium nitrite solution. Pour 2 c.c. of the concentrated hydrochloric acid down the side of the tube, mix gently and allow to stand for one minute. Add this reagent to the wool and sodium carbonate and leave for ten minutes. Withdraw the wool, rinse thoroughly to remove all loose colour and place in a test tube. Add 4 c.c. of the sodium hydroxide solution and place the tube in a briskly boiling water bath for exactly five minutes. Cool under the tap and transfer the contents to a graduated flask of suitable size. Make up to the standard volume; this solution is now ready for the colour matching.

Colour Matching

The use of the Duboscq or other type of colorimeter for this work is an advantage, but it was found in practice that quite accurate results are obtainable with Nessler tubes, as suggested by Rimington for works practice, and this method was adopted. To determine the best dilution for this purpose a sample of knitted fabric weighing 0.292 gm. was treated as above and the final solution made up to 25 c.c. The intensity of this solution was greater than that of the standard dyestuff. 5 c.c. was withdrawn, placed in the Nessler

* This is a product of British Dyestuffs Corporation (I.C.I.) and is now sold as Naphthalene Leather Brown BS.

tube and made up to 25 c.c. The standard was matched up to this by running in the dyestuff from a burette and adding distilled water to make up the volume to 25 c.c. The volume of dyestuff used was 12.2 c.c. The damage can then be expressed as a number of units on the same scale as proposed by Rimington (*loc. cit*) by including a term to represent the dilution of the wool solution. The formula becomes—

$$\text{"Damage"} = 100 \times \frac{S}{25} \times \frac{0.1}{W} \times D$$

$$\frac{S \times D}{W} \times 0.4 \text{ units}$$

S c.c. is the volume of dyestuff solution taken, W the weight of wool taken and D is the dilution of the wool solution (i.e. final volume of wool solution \div 25).

Using the above example, the damage is $\frac{12.2 \times 5 \times 0.4}{0.292} = 83.6$ units. By expressing the results in these units, it is possible to correlate all the results obtained. The dilution experiment was continued by taking a further 5 c.c. of the wool solution and diluting to 50 c.c. 25 c.c. of this solution were placed in the Nessler tube and matched as before. Four dilutions were used. The readings are shown in Table II. The greatest dilution tried was found to be the best for sensitivity of the colour matching ($D=40$).

Table II

Dilution of Wool Solution		c.c. of Dyestuff		Damage
5	...	12.2	...	83.6 units
10	...	5.9	...	80.8 "
20	...	2.9	...	79.4 "
40	...	1.5	...	82.2 "

At this dilution, the dyestuff has a yellow tint while the wool solution remains pink, so making accurate matching impossible. This difficulty was overcome by adding to the standard dyestuff a small quantity of a blue-red dye. After some experiment, Polar Brilliant Red B conc. was found to be the most suitable. The standard then had exactly the same tint as the wool solution at all comparable dilutions. The exact quantity to be added was determined by direct mixing of the two dye solutions from burettes, the mixed solutions being matched against a wool solution at various dilutions. For this purpose a 0.01% solution of the Polar Red was used. The results of this determination are given in Table III. The ratios of the two dyestuffs were calculated and the mean found.

Table III

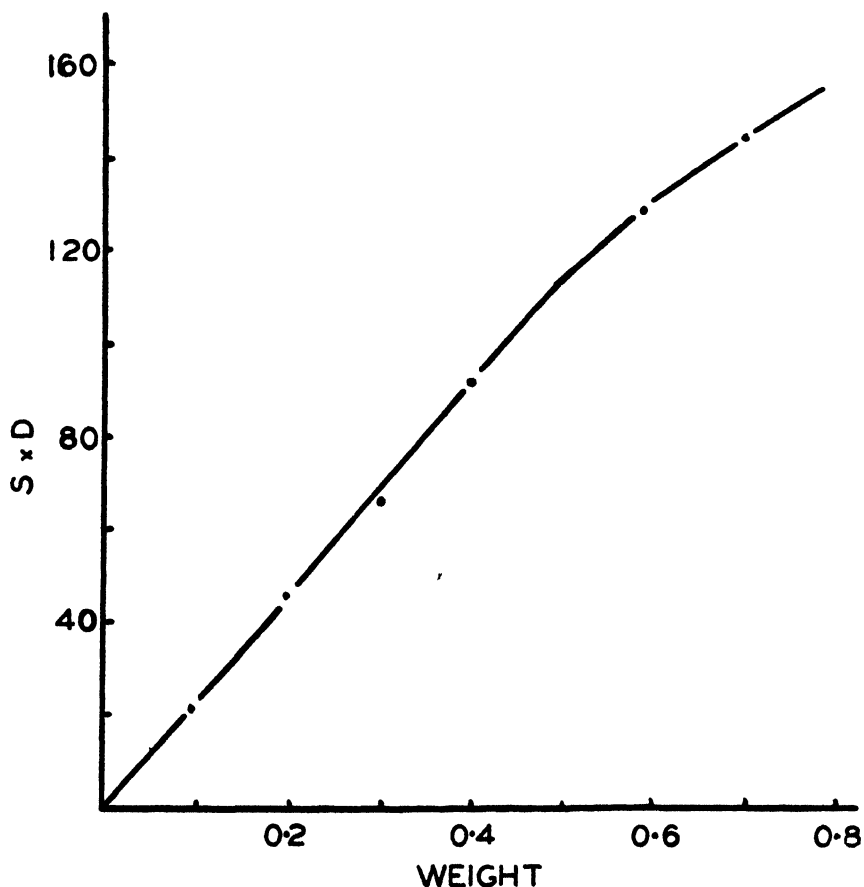
Dilution of Wool Solution		c.c. of 0.1% Standard		c.c. of 0.01% Polar Red		Ratio
10	...	4.15	...	11.75	...	2.83
20	...	1.70		4.95		2.91
40	...	0.80		2.35		2.94
80	...	0.40		1.20		3.00
160	...	0.18		0.53		2.94
						Mean = 2.925

A supply of the new standard colour was then prepared by mixing together one litre of the original and 292.5 c.c. of 0.1% Polar Brilliant Red. Table IV gives a set of results obtained with the new standard colour.

Table IV

Dilution of Wool Solution		c.c. of New Standard		S × D
10	...	12.55	...	125.5
20	...	6.30		126.0
40	...	3.10		124.0
80	...	1.60		128.0
160	...	0.80		128.0

The agreement of these results is satisfactory, showing that any dilution may be safely used with this dyestuff.

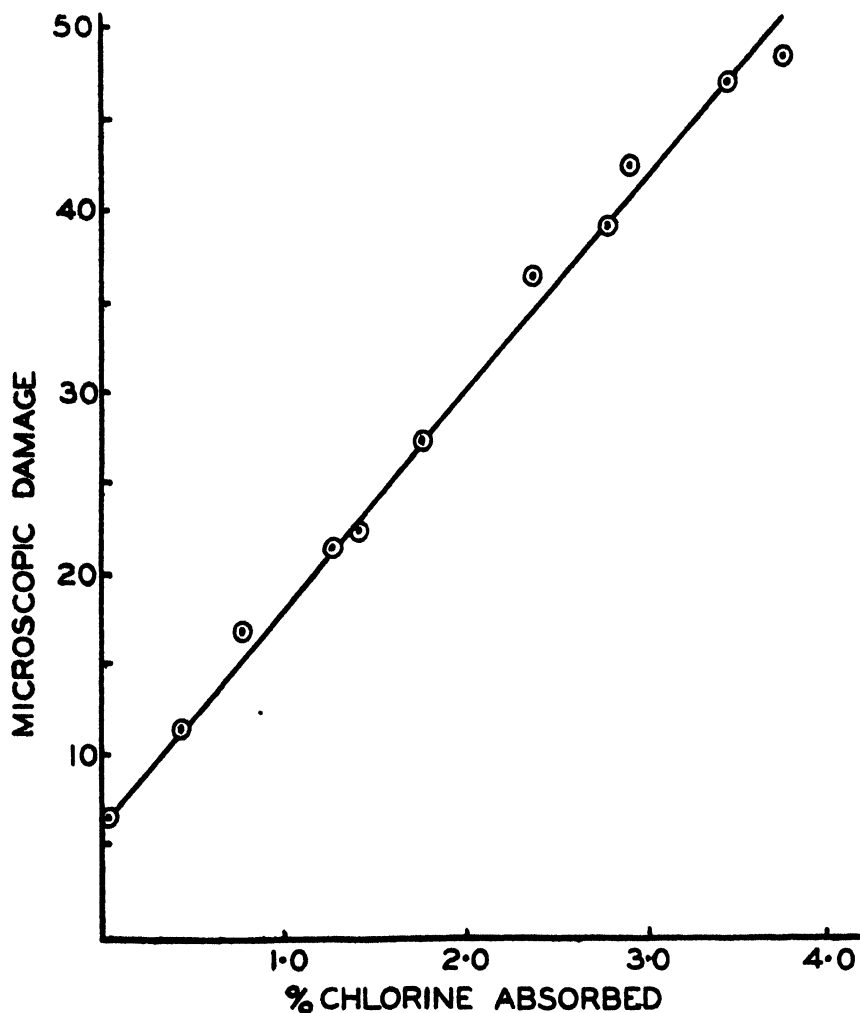
**FIG 2**

Quantity of Wool

Some experiments were made to examine whether there is a fall of stain intensity on the wool when larger samples are treated with the same quantity of reagent. For this purpose a piece of botany knitted fabric, scoured only, was used. Small pieces were cut from this to cover a range of weight. Each piece was then treated according to the specified conditions. The final solutions were made up to the convenient volumes for accurate matching. The results are given in Table V.

Table V

Weight		Dilution (D)	c.c. of Dyestuff (S)	$S \times D$		Damage
0.0962 gram	...	10	...	21.5	...	89.4 units
0.1968 "	...	20	...	46.0	...	93.6
0.3012 "	...	20	...	66.0	...	87.7
0.4004	...	40	...	92.0	...	91.9
0.4980	...	40	...	118.0	...	94.8
0.5846	...	40	...	128.0	...	87.6
0.7043	...	40	...	144.0	...	81.8


FIG. 3

To illustrate these figures a graph of $S \times D$ against weight is included. It will be seen that the curve is a straight line from zero to about 0.5 gm., after which it falls away gradually. The depth of stain is independent of the weight of wool taken up to 0.5 gm. All further experiments were made with samples of weight inside this range.

Two matters which need care were made evident during these experiments. The wool must be thoroughly wet out with the sodium carbonate solution before the reagent is added. Neglect of this causes less staining and a vitiation of the results. The final wool solution must be carefully and evenly mixed on dilution, before the colour matching process.

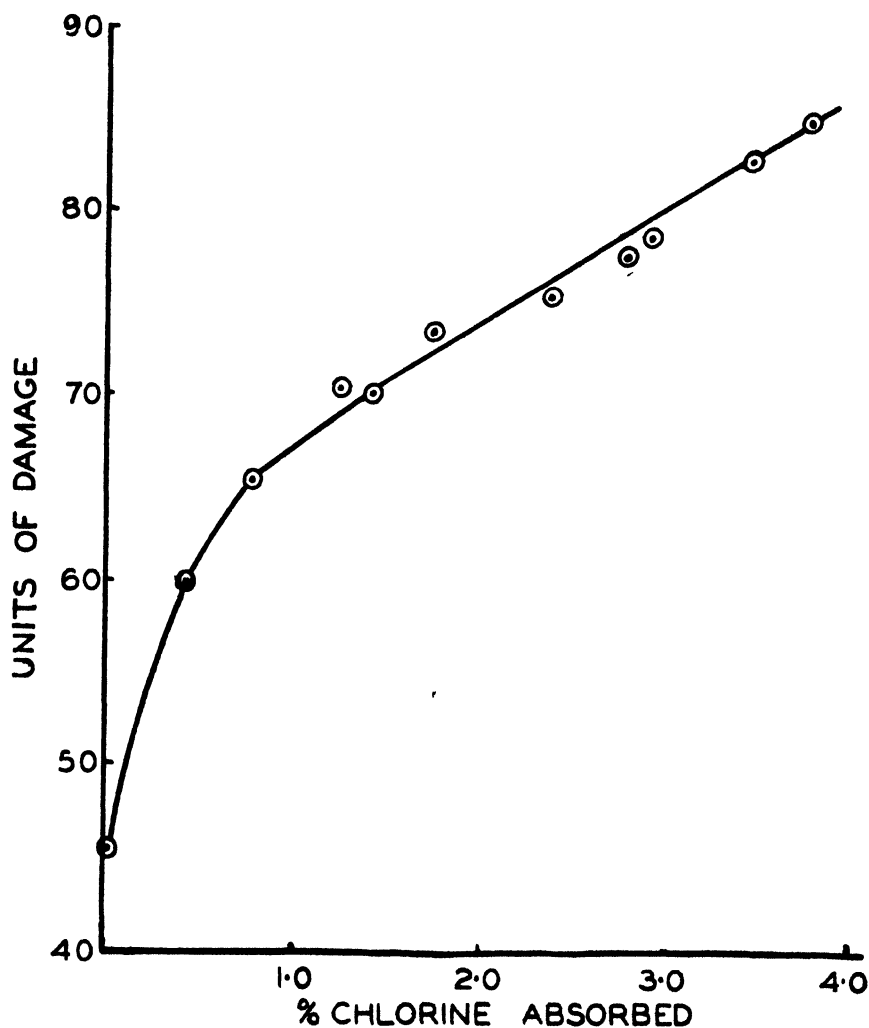


FIG. 4

Correlation of Physical and Chemical Scales

A set of samples was prepared in a series of chlorination experiments. Five-grm. pieces of fabric, knitted from a 60/2 AAA1 yarn, were treated in a sequence of baths with different quantities of chlorine, and the amount of chlorine absorbed by each sample was determined. The method of chlorination was to treat each sample of wool in a dilute bath containing a specified

quantity of standard sodium hypochlorite and sufficient hydrochloric acid to release all the chlorine. The time of treatment in each case was 45 minutes. The amount of chlorine remaining in a bath was then determined by adding potassium iodide to a 50 c.c. portion and titrating the liberated iodine with standard sodium thiosulphate. The total chlorine removed by the wool,

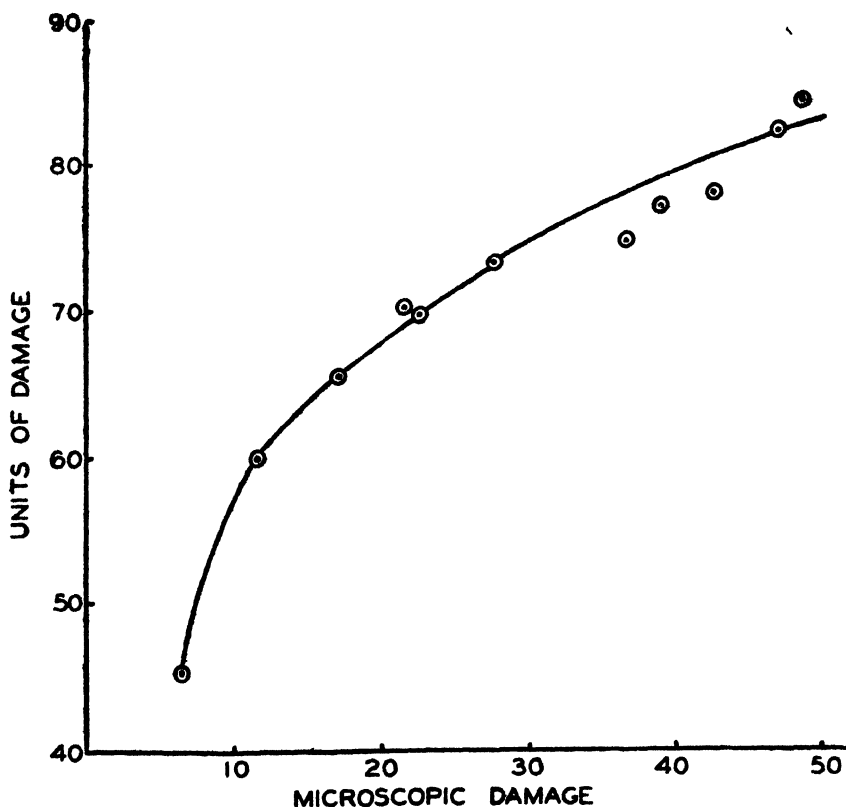


FIG. 5

including both combined and adsorbed, was thus determined by difference. The samples were then dechlorinated in a bath of sodium sulphite and sodium bicarbonate and dried. A physical and a chemical test for damage were then carried out on each sample by the methods described. For this purpose ten small pieces were cut from a sample, the total weight being about 0.15 gm. and the damage of these was then estimated by treating them together. This gives a mean figure for the damage of the sample. The microscopic count was then made on 100 fibres by taking 20 sections of yarn from the edges of the holes made for the purpose of the chemical test.

For a comparison of the effect of mechanical damage, as distinct from that caused by chlorination, an untreated sample of the same raw material was examined in the same way and the results are included in the table as a blank experiment.

Table VI

Sample No.	% of Chlorine Absorbed	Microscopic Count	Damage
Blank	Untreated	6.5%	45.2 units
1	0.42%	11.5%	60.0 "
2	0.76%	17.0%	65.6 "
3	1.25%	21.5%	70.4 "
4	1.41%	22.5%	70.0 "
5	1.74%	27.5%	73.6 "
6	2.38%	36.5%	75.2 "
7	2.79%	39.0%	77.6 "
8	2.91%	42.5%	78.4 "
9	3.46%	47.0%	82.8 "
10	3.78%	48.5%	84.8 "

Three curves are shown relating these sets of figures. Fig. 3 illustrates the ratio of physically measured damage to chlorination.

Fig. 4 shows the relation of chemically measured damage to chlorination.

Fig. 5 is the important curve which expressed the relation between readings from the physical and chemical methods.

CONCLUSIONS

Fig. 3 indicates that the number of damaged fibres is almost proportional to the degree of chlorination of the fabric, and the effect of mechanical damage is very small. Figs. 4 and 5 both show that the Pauly test becomes less sensitive for high degrees of damage, although it is quite workable over the desired range, and also that it is highly sensitive to the mechanical damage. By use of a curve of the type of Fig. 5, it is possible to use the chemical method of damage testing and to transform the results into the better-known form. This curve is definite only for the particular fabric used in the present investigation, and would certainly need modification for different wools. The amount of mechanical damage does not affect the shape of the curve, but does determine the starting point and, so, the magnitude of the measured chemical damage. For this reason, the possibility of relating chemical damage to microscopic damage is dependent always on the availability of a sample of the unchlorinated fabric for a blank experiment. Similarly, the estimation of chlorination damage by chemical means depends on the availability of untreated fabric for blank determinations. For commercial operation, therefore, the chemical method is not likely to replace the present microscopic method.

The question of the prevention of excessive damage to wool during chlorination, and the control of suitable baths, is not included in this paper, but has been discussed by the author in a further publication.⁴

In conclusion, the author's thanks are due to Mr. R. Burgess and to Mr. L. G. Richardson for their interest and advice in the course of this work.

SUMMARY

The physical and chemical methods of estimating damage in chlorinated knitted wool fabrics are examined and a way of correlating them suggested. The chosen chemical method is an extension of that put forward by Rimington. The results from this method are related graphically with those obtained from a microscopic count.

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2—THE LINEN CELLULOSE COMPLEX I—THE EFFECTS OF ALKALINE HYDROLYSIS

By E. BUTTERWORTH and H. A. ELKIN

The Effects of Alkaline Hydrolysis

The present communication records the results of an examination of the effect of alkaline hydrolysis on the flax fibre under conditions similar to those of a kier boil. It is well known that linen loses considerably in weight during the scouring operations and also that in many instances a large proportion of the alkali soluble component remains after the scouring. The present work was undertaken with the object of examining the reaction of the linen cellulose complex with alkali in the scouring operation and determining the effect of the undissolved non-cellulosic constituent in various standard tests, notably, the determination of copper number and viscosity in cuprammonium hydroxide.

The use of these tests in relation to the processing of cotton cellulose is sufficiently well known. Their use in relation to linen cellulose has not been explored. In a preliminary examination of the viscosity of a number of commercial and experimental samples of linen, certain obvious discrepancies were encountered which led to the study of the effect of the non-cellulosic components.

The linen fibre of commerce, after the normal retting and mechanical purification in preparing and spinning, contains up to 30% of material soluble in dilute alkali. The composition of this soluble component is not yet accurately known, though the character of the material composing it has been described.^{1,2,3} Its main constituent, hemicellulose, is similar in character to the linen cellulose, except that the ultimate product of hydrolysis, by dilute acids or water at high temperatures, is not glucose but a mixture of sugars, amongst which, arabinose, fucose, galactose, mannose, and xylose^{2,3} have been identified.

The methods of hydrolysis by dilute acids or water are not applicable to commercial practice by reason of the degradation of the associated cellulose and hence were not available for the purpose in view. The work was limited by these considerations to hydrolysis by dilute alkalis. A number of samples were prepared by boiling linen in a series of solutions of increasing concentration of sodium hydroxide. It was found that the weight loss increases with the concentration and so it was possible to produce a range of samples containing decreasing amounts of non-cellulosic components.

These were examined for weight loss, copper number, and viscosity. The soluble impurities are reducing in character and the copper number of the "raw" (brown) linen is found to vary from 1 to 2, according to the source and previous treatment of the material. For this reason the results given refer to one material. It has been found that the copper number falls progressively with loss of alkali soluble component. The present work was not concerned primarily with the extraction of known groups of bodies, *e.g.* pectin by ammonium oxalate, "free" hemicelluloses by 4% sodium hydroxide, etc., and a relation between copper number and any specific constituent would not be looked for, since dilute alkali at the boil removes ultimately all the non-cellulosic constituents.

The probable breakdown of the soluble bodies during the process of extraction^{10, 11, 12} prevented any immediate possibility of determining the course of the reaction. The liquors were, however, examined after the boil by

conductivity titration and it was found that there is a possibility that a definite reaction is occurring between the alkali and the soluble material. The methods used are not, however, direct enough to give positive evidence on this point and any more detailed discussion would be premature.

The viscosity of flax cellulose in cuprammonium had been found by Gibson to be of the same order as that of cotton cellulose. The values for raw flax have been found to vary to a relatively greater extent than those for cotton and for comparative purposes it is preferable to use known material. The results first obtained on the series of samples showed a minimum value which was difficult to interpret in the light of any previous work. These estimations were carried out approximately three months after preparation of

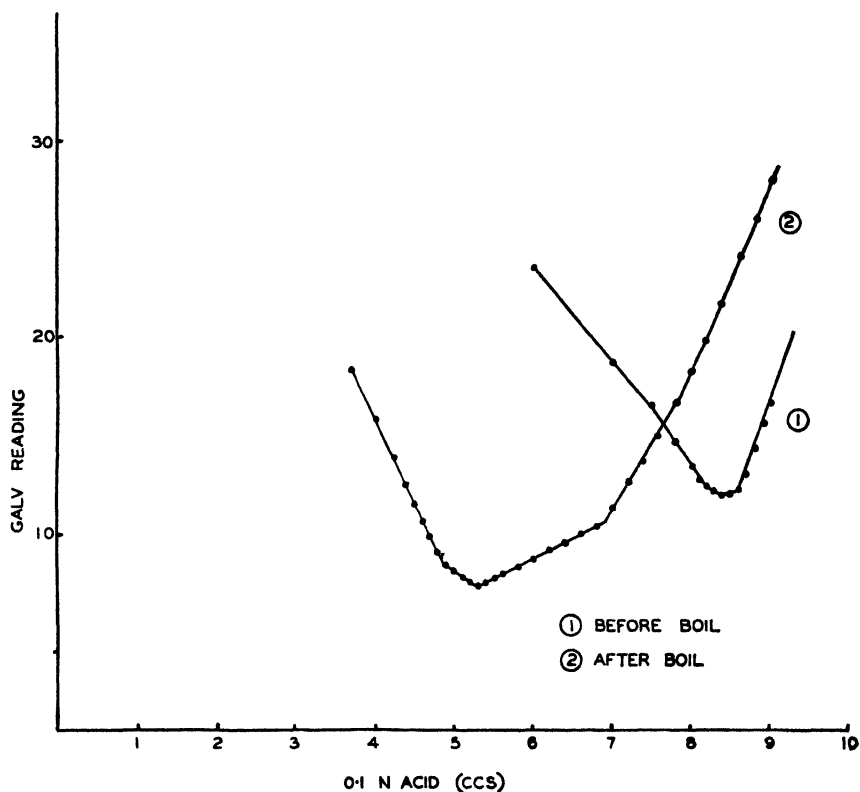


FIG. 1

the material. A further series prepared some months later, and tested almost immediately, showed no minimum. The value of the viscosity is in this case independent of the quantity of alkali-soluble component (calculated as cellulose in the determination) and is approximately constant. The determination immediately after preparation was carried out later to test a point which arose from another aspect of the work, viz. the effect of sorption of alkali.

The liquors were titrated before and after the boil by conductivity titration and it was found that the final end point (determined by the last change in curvature) always corresponded to less total alkali than was found initially, in the unused solution. This pointed to a sorption of the alkali by

the cellulose complex. On calculating the amount of alkali it was found to be an appreciable fraction of the total; moreover, the values obtained over the range of concentrations investigated (up to 2% NaOH) give a humped curve (Fig. 3), which indicates (if a real phenomenon) that a more complex reaction than sorption is occurring. These values were obtained early in the work, before the determinations of viscosity, but in view of the obscurity surrounding the effect of alkalis on sugars the subject was not pursued. Attention was again directed to these results after the peculiar form of the viscosity curves was apparent, and it was found that the maximum in the sorption curve corresponded approximately with the minimum in the viscosity curve (Fig. 5 "after three months").

If this marked sorption is real, the explanation of the fall in viscosity is clearly an ageing effect and naturally an exact correlation is not to be expected. The fall in viscosity was demonstrated on the second set of samples when tested again after two months. A marked fall was observed which was greatest in the same region as that obtained with the first set. The values are not regular and there is no question of correspondence with time, as "ageing" is a complex phenomenon. The samples were stored at constant temperature and humidity in air and light and no precise control was exercised. Determinations of alkalinity, after some months, on some of the material, by the method of Coward and Wigley⁴ showed quantities of alkali up to 0.4% to be present, though the samples had been washed thoroughly until neutral to bromo-thymol blue. The samples were not soured (a procedure suggested by other work). The fall in viscosity is not, as far as our results go, a feature of flax in general, full bleached linen or material boiled and soured has been found to give constant values over some years.

EXPERIMENTAL

The work falls into two main divisions—

- (1) Hydrolysis in sodium hydroxide solutions of concentration up to 2% at 100° C. and an examination of the solutions before and after the reaction by conductivity titration.
- (2) The examination of the scoured material, the following determinations being made—
 - (a) Per cent. weight loss.
 - (b) Copper number.
 - (c) Viscosity in cuprammonium hydroxide.
 - (d) Per cent. insoluble in cuprammonium.

The main results and conclusions have been confirmed with materials of different origins, but for simplicity of comparison the present work was carried out on one sample of Irish flax.

Material

The material chosen for this work consisted of a fabric of medium grade green yarn damask composed of Irish fibre, water retted, and wet spun. The same web of cloth was used throughout. The use of fabric, while not free from objection, was necessitated by the type of work involved. Some of the work has been repeated with good agreement, using the unretted, carefully purified fibre examined in previous work (cf. Cashmore²).

The fabric was carefully desized three times with a commercial diastase and washed until spotting tests and microscopic examination showed freedom from starch. It was dried at room temperature, since the use of high temperatures has been shown to affect the viscosity and copper number

(pp. 118 and 121). Before use the material was cut to suitable size, the edges teased out to minimise mechanical loss and conditioned to 69° F. and 73% R.H. for two to three weeks before weighing. Moisture content was determined on five samples.

ALKALINE HYDROLYSIS

It is well known that flax fibre contains up to 30% of substances soluble in boiling dilute alkalis, but no published data were available on the relationship between concentration of alkali and weight loss. Preliminary experiments showed that approximately 18% weight loss is obtained by boiling in 0.5% sodium hydroxide for four hours under reflux and a further 4% by increasing the concentration to 2 per cent. By using suitable values of initial concentration a series of samples was prepared containing up to 22% of alkali soluble component. The experiment was carried out by boiling a sample of known weight under reflux for 4½ hours in aqueous solutions of sodium hydroxide. Each of three series of determinations was carried out in duplicate.

Thus sodium hydroxide (1,600 c.c.) of the required concentration was made up and 200 c.c. was taken for estimation of concentration, by titration with decinormal acid (see below). The remaining 1,400 c.c. was divided into two portions, each of which was placed in a round bottomed litre flask. A false bottom to prevent local overheating was formed of short glass rods and the sample (30 grams) was kept immersed by longer glass rods reaching into the neck of the flask. At the conclusion of the time allowed, the liquor was transferred to a flask and cooled and the sample was quickly rinsed with hot water and finally washed with hot followed by cold water until neutral to bromo-thymol blue.

Drying was conducted at room temperature and the samples were conditioned for three weeks at 69° F. and 73% R.H. before weighing. Moisture was determined on an aliquot portion (5 grams) of each sample. Both dry and air-dry weights are then known or calculable and the weight loss may be calculated from the dry weights before and after the boil.

Table I give the initial and final concentrations of caustic soda in the liquors (columns 1 and 2) and (column 3) the per cent. weight loss sustained by the material.

It is seen from the table and in Fig. 2 that the loss in weight rises rapidly with increase in the initial concentration of alkali; thus 18% loss is obtained with 0.5% solution, while the remaining alkali-soluble component (approximately 5%) is more resistant and is not completely removed in the higher concentrations up to 2 per cent.

The alkalinity of the liquors was determined by titration with decinormal acid. Direct titration with indicators is difficult and uncertain in the case of used liquors and a conductivity method was employed using a direct reading instrument described previously.⁵ This apparatus has been shown to give comparable readings with the more usual Wheatstone bridge method. Briefly it consists of a triode oscillator (1,000 cycles per second, air core transformer) and a second triode arranged as detector.

The potential is applied across the titration cell from a third winding of the transformer in the oscillator circuit, a condenser of suitable value (0.025 mf.) being placed in series with the cell. The function of the condenser is to provide a ballasting impedance in order to maintain the current through the cell approximately constant. The voltage across the cell, measured by the anode current of the detector valve is thus, within present experimental

requirements, a measure of the resistance of the cell. Previous unpublished work had shown that the method gives accurate results in the estimation of the common acids and alkalis and the higher fatty acids and their salts. It has been found suitable in the case of mixtures of sodium hydroxide, sodium carbonate, and soaps or salts of sodium and the complex bodies in the residual liquors now being examined, where gravimetric methods are tedious and difficult. Being direct reading, the method has one advantage over the usual conductivity method in that the effect of small additions of the standard solution can be readily observed at changes of curvature where it is necessary to obtain the exact form of the curve.

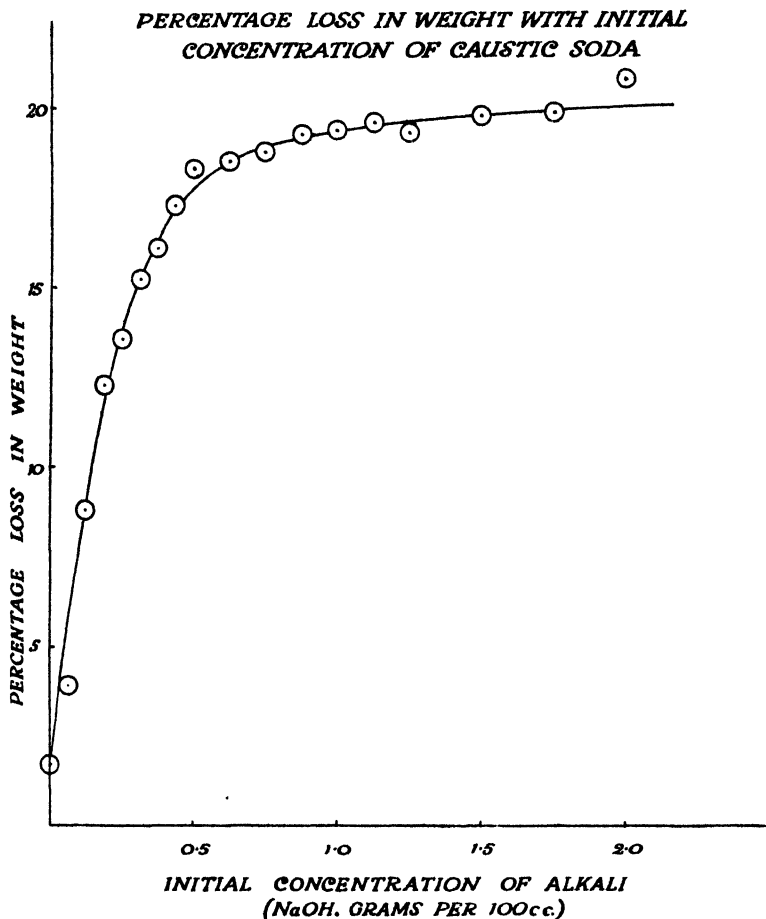


FIG. 2

The titration cell used was as given in the previous communication,⁵ platinum electrodes (not platinised) being used.

Method

A quantity of the solution equivalent to approximately 10 c.c. of 0.1N acid is measured into the cell. Distilled water is added to 100 c.c., so that the electrodes are well covered. With concentrations of this order sharp end-points are observed, with greater concentrations the changes of curvature

become progressively less distinct which renders difficult the exact determination of the endpoints.

After a steady reading of the detector anode current the acid (0.1*N* sulphuric) is added, stirring and noting the reading after each addition. When the titration is nearing the endpoint (shown by the erratic behaviour of the galvanometer during stirring) the acid is added drop by drop and when the endpoint is reached the addition of another drop of acid causes a marked increase in the conductivity of the mixture as shown by the increase in the anode current.

A few more readings are determined and a graph is plotted. Changes of curvature are then interpreted as endpoints, *e.g.* free alkali or total alkali in the solution.

One of these graphs is reproduced in Fig. 1.

Curve 1 was obtained by the titration of the solution before the boil (for comparison) while 2 was a typical curve on the residual liquor. For clarity the scales have been adjusted and the portions given represent the significant changes of curvature round the endpoints.

The first endpoint is given by the completion of the neutralisation of the free sodium hydroxide in the solution, while the final endpoint represents total alkalinity.

It is seen that even in the case of the unused solution there are two endpoints, whereas with pure NaOH only, the lines meet at a sharp angle. This is due to the presence of traces of carbonate in the solution, relatively small amounts of carbonate can be detected by this means and with larger amounts the process can be followed quite clearly, the change Na_2CO_3 to NaHCO_3 , giving a slight fall in the curve and the portion NaHCO_3 to Na_2SO_4 a slight rise to the final endpoint, where an abrupt change occurs.

The method was checked by titration of known solutions of, *e.g.* sodium hydroxide, freshly prepared from sodium in alcohol, and mixtures of sodium hydroxide and carbonate. Good agreement was observed with estimation of the same solutions, using indicators.

The curves obtained with the liquors after the reaction are complex and certain features are still obscure. The first endpoint is distinct in all cases, but the second is, in certain cases indistinct and can only be estimated approximately. This indistinctness occurred around 0.8% (initial) concentration and above and below this region the second endpoint was well defined. It is quite clear, however, that the second endpoint corresponds in all cases to considerably less alkali (total sodium) than was originally present, suggesting that some of the alkali has been sorbed by, or combined with the cellulose and contiguous material, and removed from the solution.

The form of the curves shows that some of the alkali remains after the reaction and the first endpoint is read as free sodium hydroxide.*

* Direct proof of the presence of free alkali is difficult in highly coloured solution and in the presence of cellulosic material. The slope of the first portion of the curve is, however, the same as that in the case of the curve for sodium hydroxide. This slope represents the difference in conductivity between the OH and SO_4 ions and, in the absence of side reactions, could be adduced as direct evidence of the presence of free hydroxide. Such side reactions are, for example, the precipitation of an insoluble salt. This may be ruled out as a factor and there remains the question of a possible breakdown and precipitation of a sodium complex. This case also would not invalidate the conclusion, as it has been shown, *e.g.* in the case of a feebly conducting radicle, *e.g.* a fatty acid, that the conductivity increases on addition of a mineral acid, the increase being due to the difference in conductivity between NaR and Na_2SO_4 (say). There is thus a strong probability that free sodium hydroxide is present after the reaction.

Table I

	1	2	3	4	5	6	7		8
Sample	% Concentration NaOH		% Loss in Weight	Grams Loss in Weight	Total Weight NaOH used grams	Weight NaOH Absorbed grams	% Sorption		Ratio Loss in Weight NaOH used
	Initial	Final					A	B	
A	0.00	-0.02*	1.66	0.49	0.17	0.00	—	—	2.88
B	0.06	-0.02*	3.89	1.08	0.52	0.01	—	—	2.07
C	0.12	-0.03*	8.80	2.38	0.85	0.00	—	—	2.8
D	0.18	0.01	12.26	3.39	1.18	0.25	1.03	1.03	2.87
E	0.25	0.04	13.55	3.82	1.48	0.29	1.19	1.21	2.58
F	0.31	0.07	15.19	4.43	1.62	0.37	1.47	1.51	2.73
G	0.37	0.12	16.12	4.38	1.75	0.55	2.41	2.47	2.50
H	0.43	0.17	17.28	4.99	1.80	0.66	3.58	3.78	2.76
K	0.49	0.23	18.27	5.26	1.81	0.45	1.93	1.95	2.90
L	0.61	0.32	18.54	5.36	1.88	0.54	2.28	2.26	2.86
M	0.73	0.44	18.76	5.48	1.99	1.06	4.54	4.51	2.75
N	0.87	0.58	19.25	5.51	2.06	1.33	5.75	5.33	2.72
O	1.00	0.69	19.36	5.71	2.21	1.33	5.59	5.68	2.59
P	1.12	0.82	19.63	5.72	2.11	1.13	4.80	4.86	2.72
R	1.24	0.94	19.26	5.54	2.12	1.02	4.32	4.45	2.52
S	1.52	1.15	19.78	5.55	2.47	1.06	4.70	4.79	2.25
T	1.78	1.42	19.85	5.50	2.56	1.11	5.03	5.21	2.15
X	2.04	1.68	20.77	6.07	2.47	1.37	5.95	6.18	2.46

* These liquors were faintly acid after the boil.

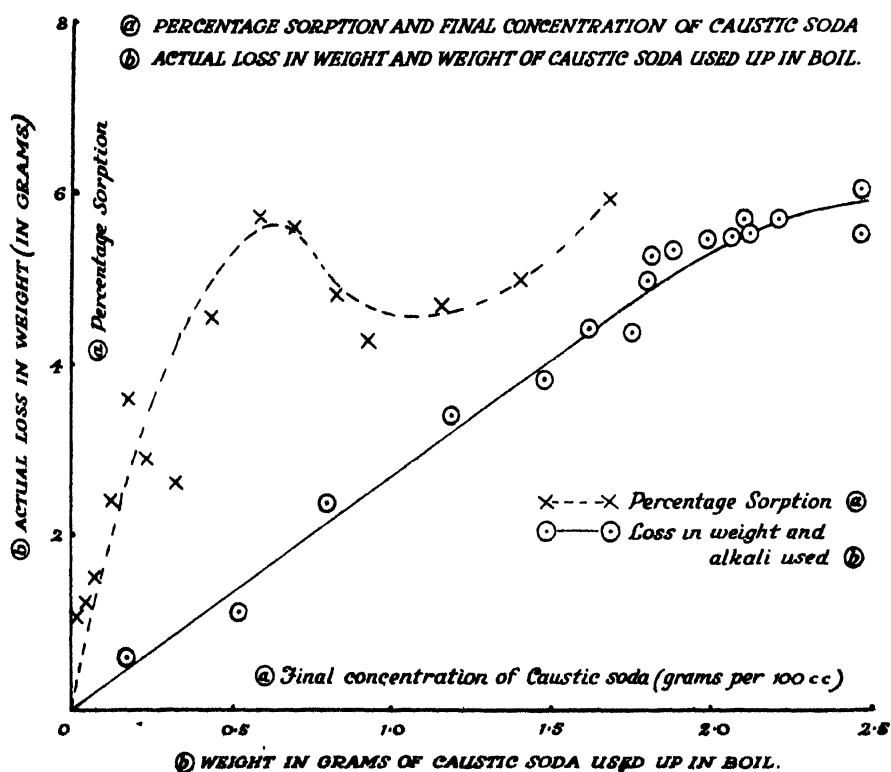


FIG 3

Assuming that a soluble sodium salt of the non-cellulosic component is the main product of the reaction, it is possible to calculate, from the values of free alkali before and after the boil, the weight of sodium hydroxide reacting. The results are given in Table I, column 5, and Fig. 3. It is apparent that a definite relationship is exhibited between the loss in weight and the alkali used up. This ratio, given in Table I, varies within relatively narrow limits with the lower concentrations and is approximately 2.8 (neglecting one abnormally low value). It appears to fall slightly as the initial concentration is increased. It should be pointed out that the amount of alkali referred to includes any sorbed or combined and removed from the solution. It is suggestive that any approach to a constant ratio is exhibited by the values, though the precise significance cannot be determined.

The values for weight loss could be repeated with fair accuracy on the same material, which points to some equilibrium being attained, since it has been shown that some of the alkali still remains after the boil. It had been found previously that (under experimental conditions) little further action occurs after $4\frac{1}{2}$ hours, thus, for example, in a solution of 0.25% NaOH, 6% loss in weight occurs after one hour, 10.2% after four hours, and 10.8% after five hours. If an equilibrium is attained, no further action should be apparent when the material is again boiled in liquor of alkalinity equivalent to that shown by the end concentration (free alkali) in the first boil. Trials to test this point show that only a slight further weight loss is observed, but the alkalinity decreases slightly and the liquor darkens appreciably, which suggests further extensive breakdown of the small quantity of soluble material.

SORPTION

As pointed out previously, the second endpoint after the boil indicated lower alkalinity than was present initially. This indicates either that some of the sodium has been sorbed by the material (and removed), or that the sodium has combined with an acid or other radicle not replaced by strong acid. The latter is most unlikely and the first is the more probable cause.

The matter may be rendered clearer by reference to the analogous case of a soap or mixture of free alkali and soap. If a fatty acid is saponified in a solution of sodium hydroxide (previously estimated on the conductivity apparatus) the form of the titration curve with acid is changed, but the final endpoint, which may be regarded as estimating total sodium, occurs at the same titre as that of the original solution of the alkali. The accuracy may, of course, be checked by indicators in "unused" solutions.

Where no previous evidence exists for the direct combination of alkali with the soluble material, any discussion is necessarily limited. It is safe to assume, however, that any "loose" complex of sodium or Na_2O would be resolved by mineral acid, so that the method should determine total alkali.

Typical figures obtained are given below, in c.c. $N/10$ acid, for two cases, to show the order of the effect.

Total alkali initially	...	...	...	(a) 9.09, (b) 14.08
After boil first endpoint	...	...	...	(a) 5.54, (b) 10.28
After boil final endpoint	...	...	...	(a) 7.21, (b) 12.06

The differences in final endpoint are of the same order as those between first and second endpoints.

The values so obtained have been calculated as grams NaOH sorbed (in comparison with the total NaOH used) and are given in Table I, column 7A, as per cent. sorption on the weight of material remaining, and Fig. 3 (plotted

against final concentration of free alkali). The calculation of sorption was made by simple difference in titre of the solution assuming constant volume of the solution and neglecting any adsorbed water, using the relation for amount sorbed $100(p-p_1)v/g$

where g =weight of cellulose material.

v =original volume of solution.

p =initial concentration of NaOH.

p_1 =final concentration of NaOH.

g is taken as the dry weight of residual cellulosic material after the reaction and concentrations in grams per 100 c.c. The above method of calculation has been criticised by Coward and Spencer⁸ and for comparison the calculation was made by their more accurate formula, using weight concentrations. It is apparent, Table I, column 7B, that the discrepancies are slight between the two methods of calculation.

It is not suggested that the calculation as sorption is justifiable in the present case, where solution of a portion of the material is taking place. Indeed it appears probable that both chemical combination, with the residual undissolved non-cellulosic component, and sorption occur simultaneously.

In view of the obvious complexity of the reactions and difficulties surrounding the interpretation of the titration curves the accuracy of the values for sorption cannot be high, but duplicate experiments (eliminating accidental errors) were consistent and support the form of the curve. The values given for each point were the means of determinations on three or more separate solutions.

The sorption has been discussed at some length since it appears to be related to the viscosity results given later.

COPPER NUMBER

The interpretation of the value obtained for the copper number depends on the previous history of the material and this test cannot be relied on to give *per se* evidence of the degree of degradation of cellulose. Thus a low copper number means strictly, presence of small quantities of reducing material and does not indicate an undegraded cellulose. A high copper number of scoured and bleached material does indicate, in the case of cotton cellulose, chemical modification.

The case of flax cellulose is more complex, since the alkali soluble components exhibit reducing properties, and the copper number of a scoured and bleached linen material affords no direct evidence of chemical degradation of the linen cellulose.

It is shown in the present work that the copper number falls progressively with increasing loss in weight and is, to a fair degree of accuracy, a measure of the percentage of non-cellulosic component remaining after alkaline hydrolysis. This can only be applied on the present data to material of known origin, and, while no serious discrepancies have been observed in the examination of other materials of different origin and treatment, any relation between copper number and non-cellulosic component is tentative. The relatively high minimum values (0.35) for the copper number are probably explained by the difficulty of removing the later fractions. Thus, by further treatment with 2% sodium hydroxide under similar conditions to those given previously,

a linen cellulose of high viscosity and low copper number (0.03) was obtained which is comparable with values obtained for similarly treated cotton cellulose.

Experimental

The determinations were carried out by the Braidy method, as described by Clibbens and Geake,⁹ but using quantities of material 1 gram to 2.5 grams (see below) according to copper number. The solutions and quantities given by these authors were adhered to and, in addition, the washing and filtration procedure was standardised as follows—

After remaining in the boiling water for exactly three hours the flask is removed and the contents immediately filtered through a sintered glass filter attached to a pump.

The fabric is impregnated with red cuprous oxide formed by the reduction of the copper sulphate by the constituents of the fabric. It is washed on the filter, first with 30 c.c. (in two portions) of the dilute sodium carbonate and then with approximately 45 c.c. of hot distilled water (three portions).

After transferring the filter and contents to a second filter flask, the fabric is treated with two portions (15 c.c. each) of the acid iron alum solution, which dissolves the cuprous oxide, an equivalent amount of the ferric salt being reduced to the ferrous state. After washing the fabric with 40–50 c.c. of the 2*N* sulphuric acid solution, the filtrates, together with the washings are titrated with *N*/25 potassium permanganate in the usual way. Blank determinations were carried out and the amount of fabric taken (1 to 2.5 grams) was adjusted by preliminary measurements, so that the amount of reduced copper required less than 10 c.c. of the permanganate in the resultant titration. With this precaution the end-point is more definite.

Clibbens and Geake,⁹ in referring to the quantity of material, state that it is necessary to adhere closely to the stated quantity 2.5 grams taken for the determination and give values for a modified cellulose, which show that the copper number increases with the amount of cellulose present. The effect of variation of quantity of material was tried first for comparison on linen and, in addition, in relation to inconsistent results obtained particularly on boiled linen. It was observed in determinations, using “brown” or lightly boiled material that some of the soluble impurities were dissolved, the solution becoming turbid and the colour changed to greenish. A proportion of the material, not completely soluble, was retained on the filter and if reducing in character might be a source of error. From the typical values given below in Table II it is apparent that for raw linen, desized at 50° C., the copper number does not show any marked increase with amount of material. In the case of boiled linen an increase is, however, observed, though in the case of the lower copper numbers the effect is relatively slight. It is stated⁹ that the effect of variation in temperature of the water bath may cause variations of 5% to 10% in copper number. Determinations of the same material on different days have given differences of the same order as those obtained using different amounts of material. Sampling is obviously important and for these comparative tests a sufficient quantity was cut up, thoroughly mixed, and weighed on the same day. For comparative values in any series of experimental samples it is preferable to carry out a dozen or more estimations on different samples and to repeat on succeeding days rather than determine several values for one sample on the same day, and this method was followed as far as possible. Most of the values lie below 1.0 and for these the usual quantity 2.5 grams was used.

Table II

Weight taken in grams	Copper Number calculated per 100 grams					
	A	B	C	D	E	
0.5	—	—	0.225	0.25	—	—
1.0	1.78	1.48	0.313	0.325	—	—
1.5	1.78	—	0.308	0.365	—	—
2.0	1.88	1.60	0.344	0.375	—	0.419
2.5	1.88	—	0.365	0.40	—	0.485
3.0	1.80	1.65	0.370	—	—	0.487

A = Brown linen desized and washed.

B = Boiled linen (low weight loss).

C = Bleached linen (three-quarter white).

D = Boiled linen (high weight loss)

E = D sample on succeeding day.

It was found in a preliminary investigation that when material containing non-cellulosic matter is dried at a low temperature (15–20° C.) the values for copper number are more consistent and this procedure was therefore used throughout. The effect of oven drying (four hours at 103°–104° C.) is shown by the following results—

Sample	Copper Number	Average
(1) A (dried room temperature) ...	1.61, 1.61, 1.61 ...	1.61
(2) A (oven dried) ...	1.37, 1.85, 1.66 ...	1.66

The series of samples obtained by alkaline hydrolysis was examined for copper number and the results are shown in Table III. From the comparison of values for percentage weight loss and copper number it is seen that the amount of non-cellulosic component present determines the copper number with fair accuracy. This is exhibited more clearly in Fig. 4, where copper

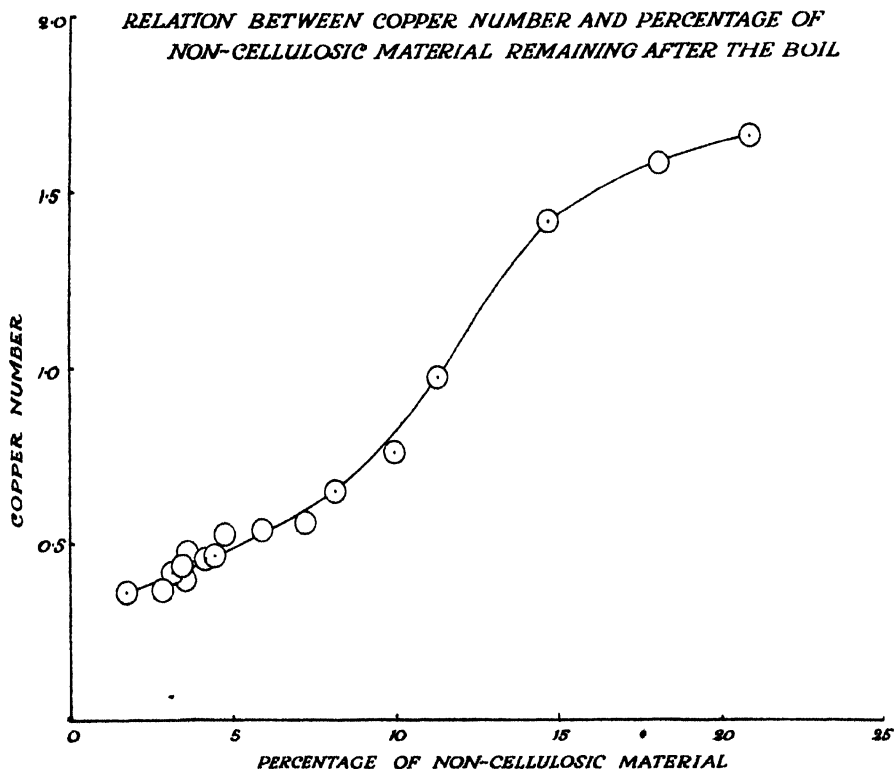


FIG. 4

number is plotted against the amount of non-cellulosic component still remaining in the fabric after the boil. The copper number rises relatively slowly at first with increasing percentage of alkali soluble component present, up to 10%, from 10–15% the rate of increase is approximately double that of the initial portion and finally a lower rate of increase is observed in the latter portion of the curve (15–22%). The actual values observed in the lower portion of the curve (below 5%) are high, probably due to retention of the more resistant portions of the alkali soluble material. A second treatment with 2% sodium hydroxide on material previously boiled in 2% solution reduces the copper number to values of the order of 0.05 with a slight further weight loss. Prolonged further hydrolysis and extensive washing gives a final product of copper number 0.01 with negligible further weight loss. This complete removal of the more resistant constituents will be examined in greater detail in later work. It is apparent, however, that the copper number weight loss relationship does not hold accurately for the earlier portion of the curve which relates to the more resistant portion of the complex.

Table III

Sample	Copper Number	Percentage Loss in Weight	Percentage Non-cellulosic Substance in Sample
A ...	1.64	1.66	20.80
B ...	1.56	3.89	18.97
C ...	1.40	8.80	14.61
D ...	0.96	12.26	11.24
E ...	0.75	13.55	9.91
F ...	0.64	15.19	8.17
G ...	0.55	16.12	7.15
H ...	0.53	17.28	5.85
K ...	0.52	18.27	4.71
L ...	0.46	18.54	4.40
M ...	0.45	18.76	4.14
N ...	0.47	19.25	3.55
O ...	0.43	19.36	3.42
P ...	0.41	19.63	3.10
R ...	0.39	19.26	3.54
S ...	0.37	19.78	2.92
T ...	0.36	19.85	2.83
X ...	0.35	20.77	1.71

The copper number falls progressively, no evidence of the relationship between copper number and any constituent is suggested by the results. The possibility of the partial breakdown *in situ* of the alkali soluble material by the hydrolysis was not overlooked (cf. Nef and others^{10,11,12}) and consideration of the results is at present confined to the copper number weight loss relationship which has been confirmed in duplicate determinations.

VISCOSITY IN CUPRAMMONIUM HYDROXIDE

In relation to the determination of the viscosity of linen cellulose with reference mainly to the effect of commercial processing it was found necessary to examine the behaviour of the non-cellulosic material, since previous critical published work has been carried out on cotton cellulose. The samples previously obtained by alkaline hydrolysis were therefore examined with the results given below.

The method adopted follows the lines laid down by previous workers in the precautions to exclude the effects of air and light on the viscosity of the cellulose solutions.

Flax fibre, in the raw or partially purified state, contains an appreciable quantity of insoluble material and this renders the determination of viscosity difficult or impossible owing to the turbidity of the solution. This difficulty was overcome by filtering the solutions, after shaking overnight, through a fritted glass filter (coarsest grade obtainable). The filtration allowed the ready determination of percentage insoluble matter, necessary as a correction of the concentration of the solution.

Preparation of the Solvent

The method of preparation of the cuprammonium hydroxide was based on the method used by Joyner¹⁵ of bubbling air through a mixture of copper turnings and ammonia. The main objection to this method is the formation of nitrous acid by oxidation of the ammonia, and Clibbens and Geake¹⁸ have shown that the nitrite content of the solution should be below 1 gram per litre (calc. as HNO_2). After trials, copper powder (reduced by hydrogen) was used instead of copper turnings.

The reaction mixture has initially the following composition —

- 150 grams copper powder (reduced by hydrogen).
- 2 litres aqueous ammonia (.880).
- 2 grams cane sugar.

The mixture is stirred at approximately 300 r.p.m. in an earthenware jar (*i.e.* out of light). The stirrer is made of iron tubing with T pieces top and bottom. Holes at the end of these T pieces are arranged so that the rotation causes air to be passed through the liquid. This method of aeration proved satisfactory with the first few batches of copper powder used, about 16 grams per litre solution, being dissolved in nine hours. The rate of solution has varied considerably with different supplies of copper and it has been found necessary to increase the rate of aeration. This can be controlled within fairly wide limits (up to 1 litre per minute) by the use of the rubber tubing pump described by Bayliss and Müller.¹⁹

Following the usual practice the air is passed through a tower containing concentrated ammonia to prevent excessive loss of ammonia from the solution. This method has been found satisfactory and a solution of cuprammonium hydroxide has been prepared containing 45 grams of copper per litre with low nitrite content.

Normally under the above conditions a solution containing 16 to 20 grams copper per litre is obtained after five to six hours stirring. The nitrite content never exceeds 0.1% and is usually about 0.05%.

The choice of a standard solution of cuprammonium hydroxide is arbitrary, since cellulose is soluble in this reagent when the copper content is greater than 10 grams per litre.¹⁵ The viscosity of the cellulose solutions is almost independent of the copper concentration above 14 grams per litre, hence most of the recent workers have used solutions containing 14 to 15 grams of copper per litre (cf. Farrow and Neale¹⁶).

For similar reasons and, further, to obtain results on linen cellulose comparable with those obtained with cotton, a concentration of 14.8–15.0 grams of copper and 230 grams ammonia (NH_3) per litre has been used throughout the present work.

The ammonia was estimated by direct titration and the copper and nitrite by modifications of standard methods.²⁰

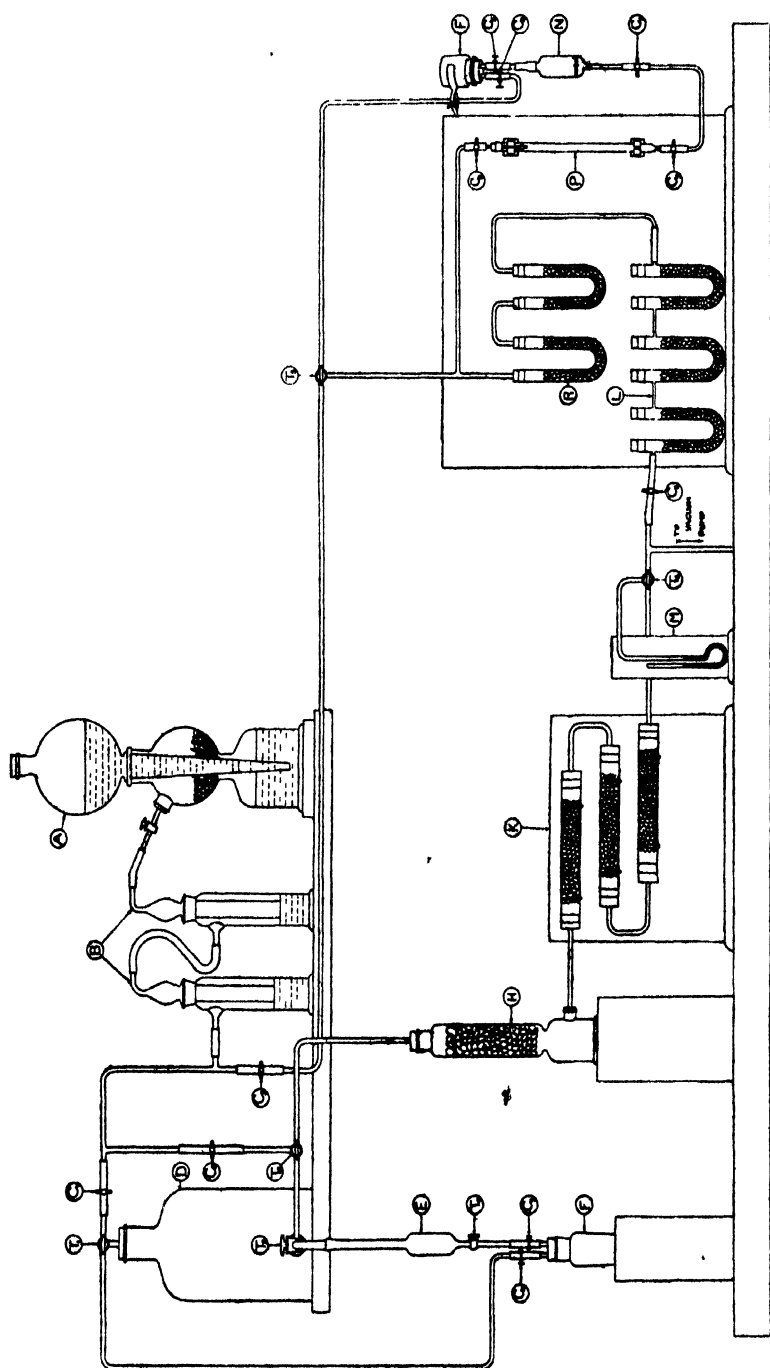


PLATE 1

Preparation of Cellulose Solutions

It has been shown^{14, 15} that the viscosity of cellulose is rapidly reduced by the presence of air and light, and the usual procedure is to carry out the dissolution *in vacuo* and protect the solution from the action of light. Farrow and Neale¹⁶, recognising the difficulty of totally excluding air, carried out the dissolution in an atmosphere of hydrogen. The method adopted follows their procedure, a sketch of the apparatus (Plate I) is given and detailed description is unnecessary. The solution, which takes place in an atmosphere of hydrogen, is carried out in a brown glass bottle F in order to exclude light. The whole operation is performed in a dark room, illuminated only by artificial light to protect the solution from light effects during the necessary exposure while filling the viscometer tubes. The apparatus has been in use since 1928 and has continually given consistent results. That the precautions are adequate is shown by the fact that the viscosity of several samples fell only about 5% after standing in the tubes for three weeks in the dark. It may be noted as a matter of interest that more concentrated solutions of cuprammonium hydroxide, *e.g.* containing 40 to 45 grams copper per litre are themselves extremely unstable to light. Such a solution placed a few feet from an electric light, deposited a film of copper on the side nearer the light after about two hours.

ESTIMATION OF THE INSOLUBLE MATTER AND THE FILLING OF THE VISCOMETER TUBES

After 24 hours' shaking, the solutions of linen cellulose usually contain a quantity of undissolved material, mainly sprit (*i.e.* lignocellulose) and epidermis, which is not dissolved by further shaking. It is necessary before measuring the viscosity of the solution to remove this insoluble component and to estimate its weight, in order to correct the calculated concentration of the solution. For this purpose one of the delivery tubes from the bottle F is attached to the weighed Jena glass filter N, which is then connected to the bottom of the viscometer tube F. The other end of the viscometer tube is connected to the pump circuit and to the hydrogen supply. The other delivery tube from the bottle F is connected to the hydrogen supply.

By exhausting after washing out with hydrogen the viscometer is readily filled with the solution, which is drawn through the filter. When full the viscometer tube is removed and the inlet at the top is quickly closed with a rubber tube and glass rod. This is the only time that the solution is exposed to air during its preparation, and the amount of air admitted, which is very small, since the top of the tube is saturated with ammonia, will only affect a narrow layer at the top of the solution and so will not alter the value of the viscosity, which is determined on the liquid at the bottom of the tube.

The remainder of the solution is drawn through the filter by suction, and the bottle F is washed into the filter with fresh cuprammonium hydroxide. The residue which is collected in the filter is well washed, first with cuprammonium and then with distilled water. The copper complex of the insoluble portion remains as a greenish fibrous substance. This complex is broken down with dilute nitric acid and well washed with distilled water and then with acetone, after which it is dried and weighed by difference, the weight of the filter having been determined already. Knowing the weight of the material used in the experiment, the percentage insoluble in cuprammonium is then easily calculated.

MEASUREMENT OF THE VISCOSITY

The work of Gibson and Jacobs²¹ showed that the falling sphere viscometer may be applied to the accurate determination of the absolute viscosity of liquids and, with other collaborators, Gibson¹⁴ applied this apparatus to the determination of the viscosity of cellulose solutions. The method has been developed by more recent investigators (cf. Farrow and Neale¹⁶) and has been used in this investigation. The viscometer is filled with the cellulose solution and supported in a thermostat regulated at $25^{\circ} \pm 0.02^{\circ}$ C. and after a few hours the viscosity is measured by steel balls $\frac{1}{16}$ th or $\frac{1}{32}$ nd inch in diameter, which are admitted through the small delivery tube which is held in the centre of the viscometer by a rubber bung and steadying piece. The time of fall between the last two graduation marks is noted and as the viscometer was standardised with castor oil and sugar solutions, the viscosity is readily determined.

The viscometer tubes are filled by means of the apparatus illustrated on the right-hand side of Plate I.

It is not usually possible to prepare a cellulose solution of definite concentration, although from our method of preparation the exact concentration is known. To compare the viscosities of several celluloses it is necessary to have solutions of standard concentration, and so it is imperative to obtain a relation between viscosity and concentration of cellulose solutions. Farrow and Neale¹⁶ have modified the equation given by Kendall for the viscosity of a solution, so as to be applicable directly to solutions made by adding a varying weight of cotton cellulose to a constant volume of cuprammonium. Their equation may be reduced to the form—

$$\log \eta = \log \eta_B + \frac{B(\log \eta_M - \log \eta_B)}{mB + (1-m)(\log \eta_M - \log \eta_B)}$$

where η is the viscosity of standard solution containing 1 gram cellulose in 100 c.c. cuprammonium hydroxide.

where η_B is the viscosity of the solvent.

η_M is the viscosity of a solution containing m grams cellulose in 100 c.c. solvent.

B is a constant.

Their experimental results with cotton solutions of various concentrations and viscosity agree with this equation very well. In this investigation it was assumed that the viscosity concentration relationship for linen cellulose is the same as that for cotton cellulose and the above relationship has been used to evaluate the viscosity of the solutions at a standard concentration (1%). Using an Ostwald capillary viscometer, the viscosity of the solvent was found to be 2.15. Farrow and Neale give a value $B=11$. The viscosity of a solution of known concentration being determined, the viscosity of a solution of 1% strength is easily calculated

DISCUSSION

By reason of the difficulties referred to above, the estimation of the viscosity of the samples was delayed and was made approximately three months after preparation. The results then showed a complex relationship between viscosity and amount of non-cellulosic component present in the sample (shown in Table IV and Fig. 5). Such a relation was difficult to explain in the light of previous work. The effect of increasing concentration

Table IV

Sample	Initial		Percentage		Log Viscosity	
	Concentration	of Alkali (grams	Non-cellulosic	Percentage	After	After
	per 100 c.c.)		Material in	Insoluble in	three	twelve
			Sample	Cuprammonium	months	months
A	0.00	...	20.80	5.62	1.28	1.17
B	0.06	...	18.97	5.38	1.27	1.13
C	0.12	...	14.61	3.67	1.23	0.99
D	0.18	...	11.24	3.25	1.19	0.79
E	0.25	...	9.91	2.89	1.14	0.75
F	0.31	...	8.17	2.63	0.94	0.60
G	0.37	...	7.15	2.61	1.02	0.55
H	0.43	...	5.85	2.47	0.91	0.59
K	0.49	...	4.71	2.45	0.83	0.51
L	0.61	...	4.40	2.20	0.76	0.61
M	0.73	...	4.14	2.02	0.69	0.62
N	0.87	...	3.55	2.07	0.71	0.44
O	1.00	...	3.42	1.97	0.94	0.37
P	1.12	...	3.10	1.81	0.88	0.51
R	1.24	...	3.54	1.91	0.99	0.55
S	1.52	...	2.92	1.57	1.07	—
T	1.78	...	2.83	1.54	0.96	0.67
X	2.04	...	1.71	1.71	1.07	0.42

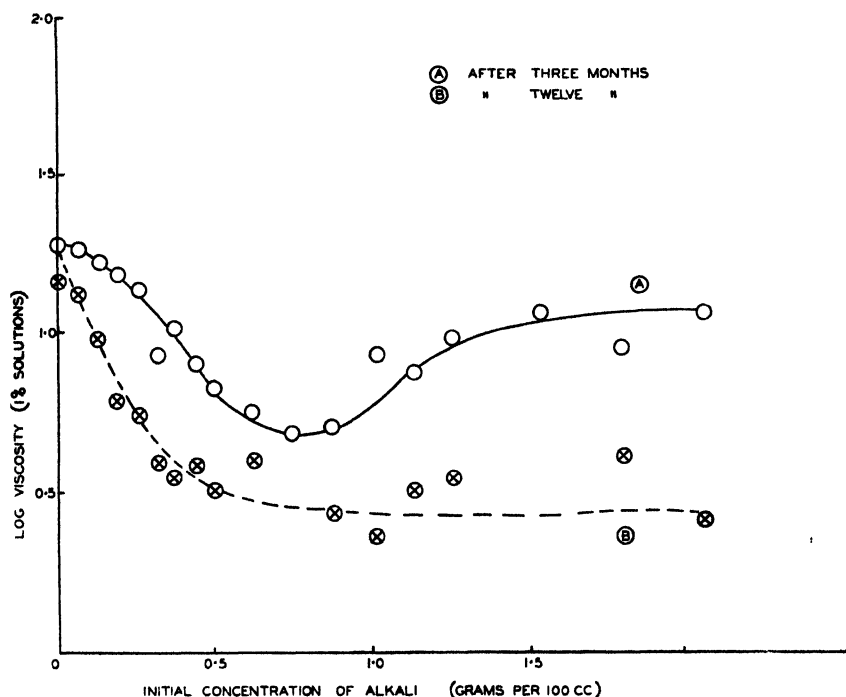


FIG. 5

of alkali in the solution is not itself sufficient, as the viscosity falls and then rises with increasing concentration. The viscosity is plotted against initial concentration of alkali for convenience, the same type of curve is exhibited, however, if plotted against percentage non-cellulosic component, except that the minimum is very sharply defined. The minimum occurs around 0.7% initial concentration NaOH, which corresponds to 4% "impurity."

On determining the viscosity about 12 months after preparation, it was found that a further fall in viscosity had occurred, though in this case no minimum is observed and the values fall progressively.

The minimum observed after three months was thus largely fortuitous and no obvious significance could be attached to the form of the curve.

Nothing was known of the possible effect of associated non-cellulosic impurities on the viscosity of cellulose, but there seemed to be no *a priori* reason why the viscosity should first be reduced as a portion of the alkali soluble material was removed and then rise as a further fraction was removed, unless some definite chemical linkage exists between all or any portion of the hemicelluloses and the cellulose itself. This view has been advanced (Mehta²², Cashmore²), but no direct evidence is given in the present work and some other reason was looked for.

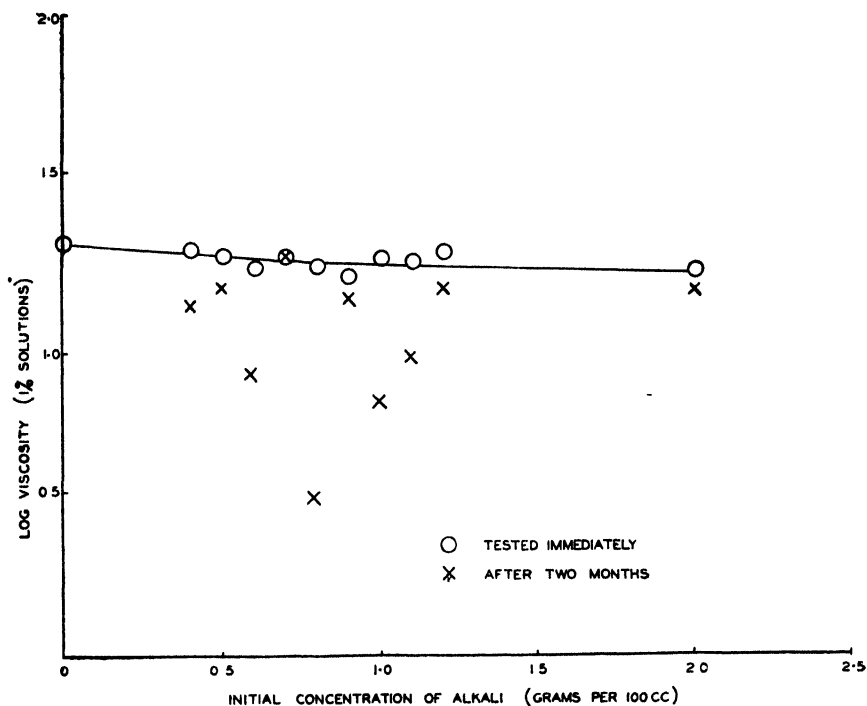


FIG 6

The possibility of a sorption of alkali was recognised from anomalies shown by the titration curves (obtained before the viscosity determinations), but this point had not been pursued. On calculating the sorption, as indicated previously, it was found that the anomalous maximum in the sorption curve corresponded with the minimum in the first viscosity curve (Fig. 5 "after three months"), which suggested a connection between sorption of sodium hydroxide and an ageing effect, causing the fall in viscosity.

This possibility was tested by repeating the preparation of some of the samples and determining the viscosity immediately after conditioning. (Two to three weeks after the hydrolysis.)

It was then found (Table V and Fig. 6) that the minimum was absent from the curve, the viscosity remaining constant with decreasing amount of non-cellulosic component. The impurities thus behave as equivalent to cellulose, since the whole is calculated as cellulose in determining the concentration of the solutions.

Table V

Initial Concentration of NaOH	Log Viscosity					
	Immediately after Preparation			After two months		
0.0	1.27	...	...	...	—
0.4	1.26	...	...	...	1.08
0.5	1.24	...	...	...	1.14
0.6	1.20	...	...	...	0.87
0.7	1.24	...	...	...	1.24
0.8	1.21	...	...	...	0.49
0.9	1.08	...	...	...	1.11
1.0	1.24	...	...	...	0.79
1.1	1.23	...	...	...	0.93
1.2	1.26	...	...	...	1.15
2.0	1.21	...	...	...	1.16

This constancy of viscosity with increasing amount of non-cellulosic constituent, while suggestive is not conclusive proof of the state of polymerisation of these bodies. It is probable, though not yet demonstrated, that the viscosity of a solution of cellulose in cuprammonium is a function of the structure of the solution. All evidence available points to the correspondence of large aggregates in the fibre and large (swollen) aggregates in the solution and vice versa.

If there is a close chemical or possibly even close physical linkage between the cellulose and all or any portion of the related substances, it is probable that the complex will swell as a unit and the resultant viscosity could not, therefore, be interpreted as definite evidence of the state of polymerisation of one member of the complex. This applies to the non-cellulosic components only, since the linen cellulose can be freed from the remainder by the alkaline treatment described.

Determinations were made of the viscosity of hemicelluloses extracted from the fibre by dilute acid under pressure (Cashmore²), but the values were low, *e.g.* 2% solution gave a log viscosity $\bar{2}.8$. The method of extraction obviously degrades the fibre material also, so that any comparison is excluded.

The ageing effect was again demonstrated by redetermining the viscosities of some of the later material after two months. Here also a fall in viscosity was observed, the greatest decrease being in the same portion of the curve as in the previous case. (Table IIIA). The values are somewhat irregular, however, two samples showed only a slight fall, and must be taken merely as substantiating the fall in viscosity. The method of experiment, "washing until neutral" to an arbitrary indicator, precludes any quantitative significance being attached to the rate or amount of the decrease.

As pointed out, the precise connection between sorption and viscosity was not observed until late, when most of the experimental material had been used. Determinations of alkalinity were made on some few samples by the method of Coward and Wigley⁴ and it was found that up to 0.4% (the maximum found) may be present in the material under the conditions described. The determination of small quantities of alkali in cellulose is attended with difficulty, as was shown by the above authors, in the case of bleached cotton, and the accuracy of the determination requires further work on the present material. The retention of alkali is surprising in view of the fact that the material was washed until neutral to bromo-thymol blue (generally overnight).

The method of "spotting" has been shown⁴ to give trustworthy results and is the usual method in practice. Bromo-thymol blue is sensitive on cotton to 0.02% alkali, so that the difference in the results by the two methods (spotting and estimation by dilute acid at the boil) is considerable.

It is recognised that a preferential sorption of acid may occur, but this is of the order of a few hundredths of 1% maximum with the concentrations of acid present in the test,²³ which is considerably lower than the values obtained for percentage alkali sorbed.

The discovery of this effect was accidental and the methods are obviously unsuitable for the determination of sorption. No stress can, therefore, be laid on the quantitative aspect of the results (sorption and ageing), but qualitatively the recognition of the effect is of obvious technical significance.

SUMMARY

(1) Flax cellulose has been examined in relation to weight loss in dilute sodium hydroxide solutions at the boil.

(2) The amount of alkali "used" has been determined by conductivity titration.

(3) "Sorption" of alkali by the complex is suggested.

(4) Copper number, determined on a series of materials containing decreasing amounts of "impurity" gives a relation between percentage impurity and copper number.

(5) Viscosity is constant with increasing amount of non-cellulosic component. Ageing of samples gives reduction in viscosity which suggests relation with sorption of alkali on samples washed, but not soured, after alkali treatment.

We have to thank the Linen Industry Research Association for permission to publish this work.

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3—THE ABSORPTION OF BARIUM HYDROXIDE, SODIUM HYDROXIDE AND WATER BY CELLULOSE, FROM AQUEOUS BARIUM HYDROXIDE AND FROM MIXED SOLUTIONS

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(College of Technology, Manchester)

INTRODUCTION

It has already been shown^{1,2} that the behaviour of cellulose in sodium hydroxide solutions can be accounted for on the hypothesis that an ionised sodium salt is formed, that the concentration of free alkali in the cellulose phase is determined by the Donnan Membrane Equilibrium, and that the amount of swelling is determined by osmotic forces.

It has also been shown that by the use of alkali solutions too dilute to cause appreciable swelling themselves, samples of cellulose in different states of reactivity on account of previous swelling treatments may be characterised by the preferential absorption of sodium or barium hydroxide.³ From solutions of the same equivalent concentration, however, barium hydroxide is absorbed roughly three times as strongly as sodium hydroxide; and, as the present experiments show, cellulose is actually less swollen in barium hydroxide than in water. This behaviour is quite inconsistent with the application to barium hydroxide of the hypothesis of ionised salt formation which was so successful in the case of sodium hydroxide. Experiments were, therefore, made in which the system cellulose-barium hydroxide-water was fully analysed, and others were carried out in which the two alkalis were used together with a view to discovering whether they reacted with cellulose merely as two bases competing for one acid. Using regenerated cellulose sheet and barium hydroxide alone, it was found that the absorption of the alkali increased steadily with the concentration, whilst the absorption of water fell, and therefore presumably the extent of swelling of the cellulose decreased. The relation between the concentration and the absorption of barium was not in agreement with the hypothesis of salt formation which described the absorption of sodium hydroxide.^{1,2} From the observation that the extent of swelling decreased with rising baryta concentration it might be inferred that the barium atoms are linked through oxygen to glucose residues in adjacent parallel chains, tending to compress the structure with expulsion of water.

In the experiments with the mixed alkalis it was found that increasing the baryta concentration decreased the absorption of sodium, but that increasing the concentration of sodium hydroxide had the effect of increasing the absorptions of both barium and sodium. This latter observation is regarded as quite inconsistent with exact similarity of mechanism of absorption of sodium and barium hydroxides, and rather suggests that the absorption of barium hydroxide by cellulose depends on the ionic product of barium and hydroxyl ions.

EXPERIMENTAL

The regenerated cellulose sheet known as "Cellophane" was used as the experimental material, after washing with water and drying in air. Several pieces were immersed for 24 hours, in a large excess of the alkali solution maintained at 25° C., removed, rapidly blotted with filter papers, weighed, titrated for total alkali, washed, dried and weighed again. The technique has already been described in detail.¹

When the mixed alkalis were used, the total alkali was determined by titration with standard acid, and the barium gravimetrically as barium sulphate.

DISCUSSION OF RESULTS

Barium hydroxide alone

The results of the experiments with barium hydroxide alone are given in Table I and shown graphically in Fig. 1. It will be seen that the absorption of barium hydroxide is much greater than that of sodium hydroxide from solutions of the same concentration. The discrepancy is still greater if preferential absorption be regarded as the significant factor, since much more water is absorbed from sodium than from barium hydroxide. It also appears that as the baryta concentration is increased, the absorption of water decreases, so that cellulose is less swollen in baryta solution than in water. This seems to indicate that the barium complex is not, like the sodium complex, of high osmotic water attraction, and in all probability ionised like an electrolyte in water, but rather that the barium atoms are more firmly bound, probably by two oxygen atoms, possibly on adjacent glucose residues, so that the structure tends to shrink and exclude water. The variation of the barium absorption with the concentration of the solutions is found to be not in agreement with the hypothesis of salt formation depending on the concentration of hydroxyl ion. The equation $\frac{b}{1-b} = Kc$

where b is the fraction $\frac{\text{equivs. Ba}}{\text{moles } C_6H_{10}O_5}$, c the baryta concentration, and K a constant describes the results quite accurately. Little theoretical significance can, however, be attached to this.

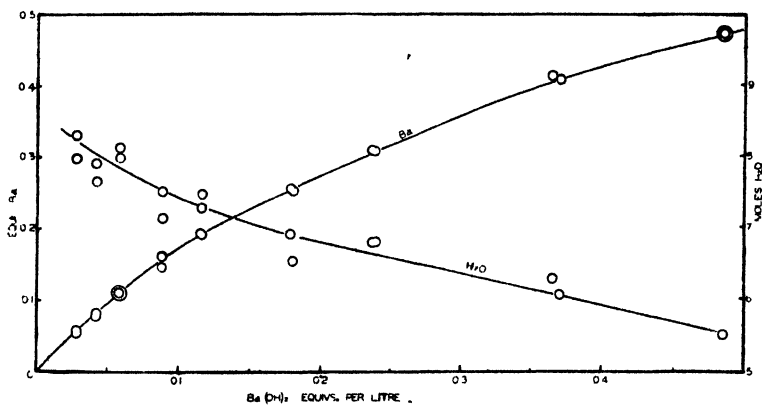


FIG. 1

Absorption of barium hydroxide and water by 162 gms. of Cellophane at 25°C.

Mixed sodium hydroxide-barium hydroxide solutions

The investigation of this three-dimensional field has been limited to two sections at right angles. One series of experiments illustrates the effect of varying the baryta concentration keeping the caustic soda concentration at about half normal, the other the effect of increasing additions of sodium hydroxide with the baryta concentration maintained at about 0.115 N.

Table I
Absorption of Barium Hydroxide and Water by Cellophane at 25° C.

Final concentration of Ba(OH) ₂ equiv./litre	0	0.028	0.0403	0.0580	0.0887
Absorption by 162 grams cellulose—					
Moles H ₂ O	8.24	7.97	7.65	8.13	7.14
Equivalent Ba	0	0.0575	0.0776	0.1114	0.1450
					0.1510

Final concentration of Ba(OH) ₂ equiv./litre	0.1167	0.1170	0.1788	0.2370	0.3702	0.3632	0.485
Absorption by 162 grams cellulose—							
Moles H ₂ O	7.47	7.27	6.90	6.63	6.81	6.06	5.50
Equivalent Ba	0.1920	0.1901	0.2550	0.2518	0.3076	0.3078	0.473

Table II
Absorption of Barium Hydroxide, Sodium Hydroxide, and Water at 25° C. from Solutions containing both Alkalis

NaOH concentration	...	...	equiv./litre	0.514	0.515	0.517	0.518	0.518	0.518	0.506
Ba(OH) ₂ concentration	...	...	...	0	0.0259	0.0255	0.0694	0.0702	0.1562	0.2358
Absorption by 162 grams of cellulose—										
Moles H ₂ O	...	...	...	9.4	11.02	10.96	8.6	8.4	8.22	8.47
Equivalent Na	...	...	...	0.234	0.2023	0.1951	0.150	0.147	—	8.11
Equivalent Ba	...	...	...	0	0.1075	0.1064	0.198	0.198	0.334	0.131
									0.335	0.408
									0.357	0.418

Ba(OH) ₂ concentration	...	...	equiv./litre	0.117	0.1137	0.1131	0.112	0.119	0.117	0.1132	—
NaOH concentration	...	...	...	0	0.4025	1.035	1.196	1.399	—	1.552	—
Absorption by 162 grams of cellulose—											
Moles H ₂ O	...	...	...	7.0	7.1	9.5	10.2	12.8	15.2	15.5	15.3
Equivalent Ba	...	...	...	0.173	0.262	0.254	0.289	0.297	0.303	0.313	0.309
Equivalent Na	...	...	...	0	0.097	0.097	0.281	0.406	0.541	0.622	0.622

The results of these experiments are recorded in Table II and in Figs. 2 and 3.

The curves in Fig. 2 show that as the concentration of baryta is increased in the presence of caustic soda at a fixed concentration, the absorption of barium increases smoothly and continuously, whilst the absorption of sodium falls. The curves are, however, by no means complementary either in shape or in magnitude. It will be noted, by comparison of Figs. 1 and 2, that the absorption of barium from these mixed solutions is always much greater than from pure baryta solution at the same concentration of barium hydroxide. The effect of barium hydroxide in decreasing the water absorption or in shrinking the cellulose is again apparent in the mixed solutions.

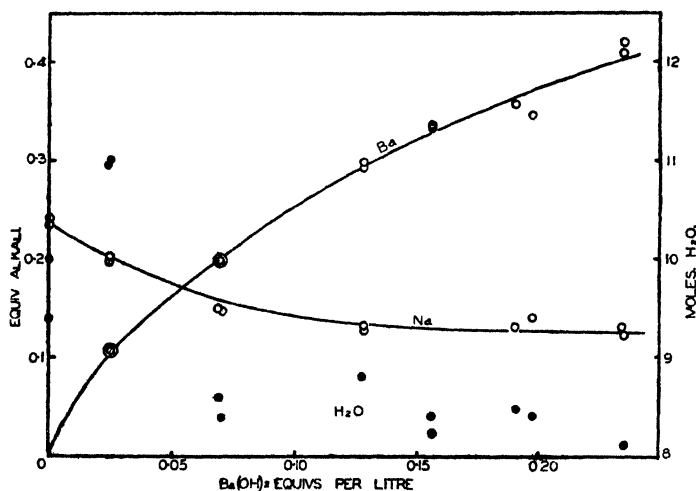


FIG. 2

Absorption of water and alkalis by 162 gms. of Cellophane at 25°C. from mixed solutions (NaOH about 0.51 N).

Fig. 3 further emphasises the remarkable fact that addition of sodium hydroxide increases the absorption of barium, and shows that the first additions of soda—up to 0.2 N—exert the greater proportion of this effect. Under the conditions represented by Fig. 3, the sodium soon becomes the predominant alkali, and this leads naturally to swelling of the cellulose and increase of the water absorption, so that the curve of total sodium absorption becomes concave upwards, as in pure caustic soda solutions.

The results which have been described are clearly incompatible with the idea of close similarity in the type of reaction between cellulose and the two alkalis. If it be assumed that the reaction with baryta—which may or may not involve elimination of water—results in attachment between adjacent hexose residue chains, a ready explanation of the shrinkage is available. It would, however, be possible to explain this effect merely by assuming that the substitution of $-O-Ba-O-$ (see footnote) for two hydroxy groups resulted in a reduced affinity for water. It has been found possible, by assuming that the extent of formation of the ionised sodium salt depends on the hydroxyl ion activity, whilst that of the barium complex depends on the activity of unionised $Ba(OH)_2$ calculated according to the methods of

Ferri-barium complexes of manitol and sorbitol containing this type of linkage have recently been described by Traube and Kuhnert (*Ber.*, 1932, 65, 187)

Lewis and Randall⁴, to reproduce at least the shape of the observed curves. It is felt, however, that only exact agreement or other proof of the hypotheses would justify the publication of the somewhat intricate calculations in full.

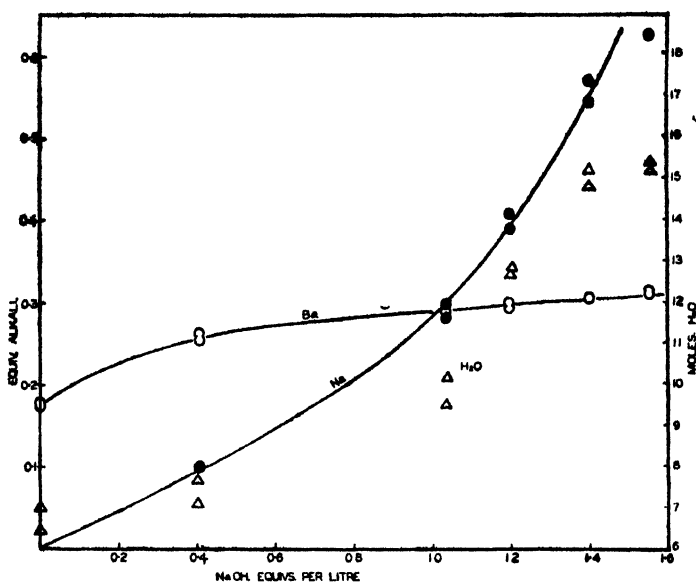


FIG. 3

Absorption of water and alkalis by 162 gms. of Cellophane at 25° C from mixed solutions ($\text{Ba}(\text{OH})_2$ about 0.115 N)

It has been found necessary in this connection to determine the solubility of barium hydroxide in dilute sodium hydroxide solutions, and the results of these measurements are published elsewhere⁵.

SUMMARY

1—The absorption of barium hydroxide, sodium hydroxide and water by cellulose sheet from pure baryta and from mixed solutions has been determined

2—In pure baryta solutions the absorption of barium rises steadily with the concentration; the absorption of water falls.

3—In mixed solutions addition of baryta decreases the absorption of sodium, but addition of caustic soda increases the absorption of barium.

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4—EXAMINATION OF A PROPOSED RELATIONSHIP BETWEEN THE LEA TEST AND THE SINGLE THREAD TEST RESULTS

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I—INTRODUCTION

Of the various methods used for determining the strength of yarns the two which are most commonly employed are the lea test and the single thread test. Each of these has its own peculiar advantages and disadvantages and neither is, therefore, completely satisfactory. The lea test is fairly simple in manipulation, involves a comparatively small sampling error and, provided a fairly large number of readings are taken, is capable of distinguishing between two yarns with an accuracy which is sufficient for all practical purposes. Besides, it has the sanction of time and the force of general usage in its favour. On the other hand, it gives no indication of the elasticity of a yarn, attaches undue importance to the presence of relatively weak yarns in a lea, which, breaking with increasing load, result in the slippage of free ends. Moreover, the rate of loading is not strictly constant but depends upon the angle which the arm supporting the heavy pendulum makes with the vertical.¹ Furthermore, the time factor, upon which the strength of a yarn depends to some extent, is called into play by the different extensibilities of different yarns.² The effect of the last-mentioned factor is not serious if yarns having very unequal breaking strength are tested by this method, but is quite appreciable if the choice has to be made between two yarns having nearly the same breaking strength but different extensibilities. The single thread test is free from many of these objections; but, unless an inconveniently large number of tests are made, the total length of yarn used up in this test is so small that the sampling error may be very large.

Very often both tests are made on the same sample of yarn, so that not only the results of one serve as a check upon the other, but the information regarding yarn characteristics lacking in one test is supplied by the second. This has been the practice at the Technological Laboratory. The results of a very large number of tests have shown that, although there is a general correspondence between the two tests,³ it is not always possible to foretell with certainty the mean value of one test from that of the other. Not infrequently cases arise when there is a wide gulf between the results of lea and single thread tests. Thus, between two yarns, A and B, the lea test may indicate a difference in strength of 10% only, while according to the single thread the difference may be as much as 30 or 40 per cent. Consequently, it has always been found necessary, even at the expense of considerable time, to perform both tests. It follows, therefore, that if by analysing the individual readings of the single thread test, it should become possible to deduce, with a fair degree of accuracy, the lea breaking strength of the same yarn, it would greatly benefit the research laboratories which are called upon to test a large number of samples in the course of a year, as it would result in a considerable saving of time.

Recently, Gregson⁴ has suggested such a method of analysing the results of 160 single thread tests, in which the threads are regarded as forming a hypothetical lea, and the effect of rupture of weak threads, with gradually

increasing load, is taken into consideration. He has shown that, *in the particular case considered by him*, the lea test of the yarn sample could be predicted from such an analysis, and that good agreement was obtained between the predicted and the actual lea breaking strengths. This attempt to establish a connection between the two tests is interesting in more than one respect, and, if Gregson's method could be shown to be applicable to yarns spun from different cottons, it would constitute an important advance in the practice of testing cotton yarns. But, as mentioned above, Gregson has considered only one case in his paper, and, in view of the variability which is an ever-present feature of tests on cotton, it is not safe to base reliable conclusions on a single case. The object of this paper is to apply Gregson's method to results of single thread and lea tests on 144 carded and combed yarns, ranging in counts from 6's to 80's, and spun from 16 standard Indian cottons of 1931-32 season.⁵ For the finer counts (50's and above) two long staple Indian cottons were combed to the extent of 20% and 30% and spun on the ordinary as well as a four-roller high draft system. All cottons were spun in duplicate lots into two or more suitable counts, according to their spinning capacity. Twenty single thread tests and five lea tests had been made on each of the ten bobbins of carded yarn, but, as only 160 single thread test results are required in Gregson's method, the results of the first eight bobbins only are considered. However, as only ten single thread tests had been made on each bobbin of the combed yarns, each result relating to the first eight bobbins was regarded as equal to two, so as to obtain 160 results in all. It may be mentioned that in view of the fact that in the present paper the results of tests on the first eight bobbins only have been considered, there may be slight differences between the mean values given here and those given in the Technological Reports on Standard Indian Cottons, 1932.

II—EXPERIMENTAL DETAILS

The lea tests were made on an electrically driven Goodbrand's Lea Tester No. 18, which had a speed of the lower jaw equal to 12 inches per minute. The lea is simply slipped between the upper and the lower hooks and neither of the two ends is fastened by a knot. The single thread tests were made on successive 12 in. lengths of yarns on Goodbrand's Single Thread Tester No. 20, which has the same rate of traverse of the lower grip as the above-mentioned lea tester.

Other factors being equal, the strength of a yarn will decrease up to a limiting value with its length, as in a longer specimen the weak places would be more numerous than in a short one.⁶ Now in the lea test the length of yarn is about 27 in., while in the single thread test only 12 in. of yarn is subjected to tension. For this reason alone, therefore, the results of the two tests are not strictly comparable. Fortunately, systematic experimental work, with a different object, has been done at the Technological Laboratory on the strength of multiple single lengths of yarn, including 12 in. and 30 in., from which it is possible to apply a correction on this account. It is found that on the average the single thread strength for 30 in. lengths is some 6% less than that for 12 in. lengths. Accordingly, although Gregson does not mention the yarn length employed by him in his single thread tests, in the present treatment the comparison between the predicted and the actual lea strength values is made with and without applying this correction.

Table I

Disparity between Lea and Single Thread Results

Standard Indian Cottons, 1931-32

(Carded Yarns)

Sample No	Cotton	Counts Nominal	Lea Ratio (%)	S T Strength (oz)	Lea Strength (lb)	Lea Strength derived from S T Results (lb)	(%) Difference	Lea Strength after applying 6% Correction (lb)	(%) Difference
1304/1	Jayawant	20A	79	11.9	93.6	87	- 7.1	81.8	-12.6
1304/2		"	80	11.8	94.4	90	- 4.7	84.6	-10.4
1304/1		20B	81	12.1	98.6	98	- 0.6	92.1	- 6.6
1304/2		"	77	12.7	97.2	100	+ 2.9	94.0	3.3
1304/1		30	73	7.3	53.4	55	+ 3.0	51.7	- 3.2
1304/2		"	80	7.1	55.5	53	- 4.5	49.8	-10.3
1304/1	Gadag 1	34	66	6.6	43.8	50	+14.2	47.0	+ 7.3
1304/2		"	66	6.9	45.4	52	+14.5	48.9	+ 7.7
1305/1		20A	72	10.6	75.8	82	+ 8.2	77.1	+ 1.7
1305/2		"	76	11.2	85.3	89	+ 4.3	83.7	- 1.9
1305/1		20B	72	10.9	78.5	87	+10.8	81.8	+ 4.2
1305/2		"	82	10.5	85.6	82	- 4.2	77.1	- 9.9
1305/1	1027 A.L.F.	30	65	7.0	45.8	52	+13.5	48.9	+ 6.8
1305/2		"	71	6.9	49.0	52	+ 6.1	48.9	- 0.2
1305/1		34	67	5.5	37.1	39	+ 5.1	36.7	- 1.1
1305/2		"	70	5.6	39.2	42	+ 7.1	39.5	+ 0.8
1313/1		20A	75	10.7	80.5	81	+ 0.6	76.1	- 5.5
1313/2		"	70	12.1	84.6	93	+ 9.9	87.4	+ 3.3
1313/1	Wagad 8	20B	79	11.5	90.5	87	- 3.9	81.8	- 9.7
1313/2		"	71	12.5	88.6	98	+10.6	92.1	+ 4.0
1313/1		30	66	7.7	50.9	60	+17.9	56.4	+10.8
1313/2		"	64	8.1	51.8	61	+17.8	57.3	+10.6
1313/1		34	63	6.3	39.8	46	+15.6	43.2	+ 8.5
1313/2		"	67	6.0	40.2	43	+ 7.0	40.4	+ 0.5
1300/1	4F	10	79	18.3	145.3	144	- 0.9	135.4	- 6.8
1300/2		"	75	19.5	146.1	154	+ 5.4	144.8	0.9
1300/1		14	75	14.1	106.3	114	+ 7.2	107.2	+ 0.9
1300/2		"	72	14.8	107.0	113	+ 5.6	106.2	- 0.8
1300/1		16	73	11.7	85.0	88	+ 3.5	82.7	- 2.7
1300/2		"	70	12.2	85.3	90	+ 5.5	84.6	- 0.8
1243/1	289F	20	63	10.4	65.5	79	+20.6	74.3	+13.4
1243/2		"	71	9.9	70.2	71	+ 1.1	66.7	- 5.0
1243/1		24A	61	8.5	52.1	63	+20.9	59.2	+13.6
1243/2		"	65	8.2	53.4	61	+14.2	57.3	+ 7.3
1243/1		24B	67	8.7	58.2	66	+13.4	62.0	+ 6.5
1243/2		"	63	8.7	54.6	67	+22.7	63.0	+15.4
1239/1	Mollison	20	85	12.1	102.9	95	- 7.7	89.3	-13.2
1239/2		"	75	13.2	99.3	103	+ 3.7	96.8	- 2.5
1239/1		30	78	7.5	58.4	58	- 0.7	54.5	- 6.7
1239/2		"	70	8.0	55.8	58	+ 3.9	54.5	- 2.3
1239/1		40	75	5.2	38.8	38	- 2.1	35.7	- 8.0
1239/2		"	67	5.5	36.6	39	+ 6.6	36.7	+ 0.3
1240/1	A19	8	60	15.9	95.5	113	+18.3	106.2	+11.2
1240/2		"	69	16.7	114.9	123	+ 7.0	115.6	+ 0.6
1240/1		10A	65	10.3	66.6	6	- 2.4	61.1	- 8.3
1240/2		"	63	10.8	68.0	76	+11.8	71.4	+ 5.0
1240/1		10B	69	11.6	79.7	81	+ 1.6	76.1	- 4.5
1240/2		"	73	11.6	84.1	87	+ 3.4	81.8	- 2.7
1286/1	A19	6	55	16.6	91.8	111	+20.9	104.3	+13.6
1286/2		"	59	13.9	82.2	85	+ 3.4	79.9	- 2.8
1286/1		8A	39	12.9	50.0	85	+70.0	79.9	+59.8
1286/2		"	58	11.0	63.4	63	- 0.7	59.2	- 6.6
1286/1		8B	47	13.1	61.3	88	+43.6	82.7	+34.9
1286/2		"	63	11.8	74.2	76	+ 2.4	71.4	- 3.8

TABLE I—continued

Sample No.	Cotton	Counts Nominal	Lea Ratio (%)	S.T. Strength (oz.)	Lea Strength (lb.)	Lea Strength derived from S.T. Results (lb.)	(%) Difference	Lea Strength after applying 8% Correction (lb.)	(%) Difference
1227/1	K22	10	74	14.7	109.4	106	- 3.1	99.6	- 8.9
1227/2		"	61	16.4	99.9	109	+ 9.1	102.5	+ 2.6
1227/1		12	78	12.6	98.4	96	- 2.4	90.2	- 8.3
1227/2		"	84	12.4	103.6	88	- 15.1	82.7	- 20.2
1227/1	C.A.9	14	69	11.3	77.5	81	+ 4.5	76.1	- 1.8
1227/2		"	71	10.8	76.5	77	+ 0.7	72.4	- 5.4
1265/1		20	77	12.6	96.4	97	+ 0.6	88.5	- 8.2
1265/2		"	78	13.4	104.7	107	+ 2.2	100.6	- 3.9
1265/1	Verum Nagpur	30	70	8.1	57.1	62	+ 8.6	58.3	+ 2.1
1265/2		"	79	7.7	61.2	56	- 8.5	52.6	- 14.1
1265/1		34	68	6.7	45.4	47	+ 3.5	44.2	- 2.6
1265/2		"	79	6.6	52.3	50	- 4.4	47.0	- 10.1
1265/1	Verum Akola	40	67	4.7	31.5	33	+ 4.8	31.0	- 0.2
1265/2		"	74	5.0	36.9	35	- 5.1	32.9	- 10.9
1242/1		20	73	11.0	80.0	80	0	75.2	- 6.0
1242/2		"	70	11.4	80.1	87	+ 8.6	81.8	+ 2.1
1242/1	Umri Bani	26	61	8.7	53.3	64	+ 20.1	60.2	+ 13.0
1242/2		"	62	8.4	52.4	62	+ 18.3	58.3	+ 11.3
1242/1		30	65	6.6	42.6	47	+ 10.3	44.2	+ 3.8
1242/2		"	61	6.5	38.9	45	+ 15.7	42.3	+ 8.7
1241/1	Hagari 1	16	69	13.8	95.2	101	+ 6.1	94.9	- 0.3
1241/2		"	85	11.2	94.8	84	- 11.4	79.0	- 16.7
1241/1		20	72	10.3	73.8	75	+ 1.6	70.5	- 4.5
1241/2		"	71	9.3	65.9	65	- 1.4	61.1	- 7.3
1241/1	Hagari 25	26	66	7.2	47.6	45	- 5.5	42.3	- 11.1
1241/2		"	65	6.9	44.7	48	+ 7.4	45.1	+ 0.9
1228/1		20	67	12.2	82.3	98	+ 19.1	92.1	+ 11.9
1228/2		"	67	12.6	84.4	99	+ 17.3	93.1	+ 10.3
1228/1	Hagari 1	24	67	10.2	68.6	76	+ 10.8	71.4	+ 4.1
1228/2		"	70	10.1	70.3	77	+ 9.5	71.4	+ 1.8
1228/1		30	81	5.4	43.9	36	- 18.0	33.8	- 23.0
1228/2		"	55	7.1	39.2	51	+ 30.1	47.9	+ 22.2
1311/1	Hagari 1	20A	75	11.0	82.2	86	+ 4.6	80.8	- 1.7
1311/2		"	69	11.2	77.7	89	+ 14.5	83.7	+ 7.7
1311/1		20B	74	12.1	89.0	95	+ 6.7	89.3	+ 0.3
1311/2		"	70	11.9	83.7	90	+ 7.5	84.6	+ 1.1
1311/1	Hagari 25	30	64	7.4	47.4	53	+ 11.8	49.8	+ 5.1
1311/2		"	63	7.8	49.2	60	+ 22.0	56.4	+ 14.6
1311/1		40	68	4.6	31.1	33	+ 6.1	31.0	- 0.3
1311/2		"	60	5.1	30.6	38	+ 24.2	35.7	+ 16.6
1312/1	Hagari 25	20A	77	10.7	82.3	86	+ 4.5	80.8	- 1.8
1312/2		"	84	9.5	79.5	72	- 9.4	67.6	- 15.0
1312/1		20B	81	11.4	92.4	94	+ 1.7	88.4	- 4.3
1312/2		"	83	10.8	89.7	84	- 6.4	79.0	- 11.9
1312/1	Karunganni C7	30	73	6.7	48.7	48	- 1.4	45.1	- 7.4
1312/2		"	78	6.5	50.4	47	- 6.7	44.2	- 12.3
1312/1		40	68	4.7	31.9	33	+ 3.4	31.0	- 2.8
1312/2		"	70	4.3	30.3	31	+ 2.3	29.1	- 4.0
1320/1	Karunganni C7	20A	64	9.3	59.6	66	+ 10.7	62.0	+ 4.0
1320/2		"	66	9.5	62.4	70	+ 12.2	65.8	+ 5.4
1320/1		20B	72	9.7	70.3	69	- 1.8	64.9	- 7.7
1320/2		"	65	11.1	72.0	84	+ 16.7	79.0	+ 9.7
1320/1	Karunganni C7	26	68	6.4	43.8	44	+ 0.5	41.4	- 5.5
1320/2		"	57	8.1	46.1	58	+ 25.8	54.5	+ 18.2
1320/1		30	54	5.7	30.6	38	+ 24.2	35.7	+ 16.7
1320/2		"	54	5.6	30.0	40	+ 33.3	37.6	+ 25.3

III—RESULTS

Table I gives the name of the standard cotton, the nominal counts into which it was spun, the mean values of the single thread and the lea breaking strength of the carded yarns, the lea strength as calculated by Gregson's method and the percentage differences between the calculated and the actual values with and without the correction for different lengths of yarns employed

Table II
Disparity between Lea and Single Thread Results
(Combed Yarns)

Sample No.	Cotton	Counts Nominal	Lea Ratio (%)	S.T. Strength (oz.)	Lea Strength (lb.)	Lea Strength derived from S.T. Results (lb.)	(%) Difference	Lea Strength after applying 6% Correction (lb.)	(%) Difference
1210/1	Cambodia Co. 1	50	64	5.2	33.3	40	+20.1	37.6	+12.9
1210/2	(20% combed)	60	64	5.1	32.8	39	+18.9	36.6	+11.6
1210/1	O S	60	62	4.6	28.4	34	+19.7	31.9	+12.3
1210/2		65	65	4.4	28.6	34	+18.9	31.9	+11.5
1210/1	" H D	60	66	4.3	28.2	33	+17.0	31.0	+ 9.9
1210/2		62	62	4.5	27.7	34	+22.7	31.9	+15.2
1210/1		70	60	3.7	22.1	27	+22.2	25.4	+14.9
1210/2		66	66	3.6	23.6	26	+10.2	24.4	+ 3.4
1210/1	(30% Combed)	60	59	4.6	27.3	37	+35.5	34.8	+27.5
1210/2	O S	66	66	4.4	28.9	33	+14.2	31.0	+ 7.3
1210/1		70	57	3.5	19.9	27	+35.7	25.4	+27.6
1210/2		63	63	3.6	22.7	26	+14.5	24.4	+ 7.5
1210/1	" H D	70	66	3.7	24.6	30	+22.0	28.2	+14.6
1210/2		62	62	4.0	24.6	32	+30.1	30.1	+22.4
1210/1		80	61	3.1	18.8	23	+22.3	21.6	+14.9
1210/2		67	67	2.9	19.4	21	+ 8.2	19.7	+ 1.5
1218/1	1027 A L F	50	63	4.7	29.5	35	+18.6	32.9	+11.5
1218/2	(20% combed)	60	65	4.5	29.1	34	+16.8	31.9	+ 9.6
1218/1	O S	60	61	3.7	22.7	27	+18.9	25.4	+11.9
1218/2		65	65	3.6	23.4	27	+15.4	25.4	+ 8.5
1218/1	" H D	50	68	4.8	32.6	38	+16.6	35.7	+ 9.5
1218/2		79	79	3.9	30.7	28	- 8.8	26.3	-14.3
1218/1		60	90	2.7	24.3	20	-17.7	18.8	-22.6
1218/2		78	78	3.2	24.8	25	+ 0.8	23.5	- 5.2
1218/1		70	77	2.3	17.6	18	+ 2.3	16.9	- 4.0
1218/2		78	78	2.3	17.9	16	-10.6	15.0	-16.2
1218/1	(26% Combed)	60	75	3.1	23.2	24	+ 3.4	22.6	- 2.6
1218/2	O S	70	74	3.2	23.7	24	+ 1.3	22.6	- 4.6
1218/1		68	68	2.4	16.2	17	+ 4.9	15.9	- 1.9
1218/2		73	73	2.3	16.8	17	+ 1.2	15.9	- 5.4
1218/1	" H D	60	61	3.8	23.2	28	+20.7	26.3	+13.4
1218/2		63	63	3.6	22.6	27	+19.5	25.4	+12.4
1218/1		70	77	2.2	17.0	16	- 5.9	15.0	-11.8
1218/2		74	74	2.4	17.8	17	+ 4.5	15.9	-10.7

(O S = Ordinary single roving H D. = High draft.)

in the two tests. Table II gives the same data for the combed yarns. Besides these a quantity, called the "lea ratio," has been calculated which represents the percentage ratio of the lea strength to 160 times (the number of threads in a lea) the single thread strength. It will be seen from the following discussion that Gregson's method is approximately valid only if the "lea ratio" lies between certain limits.

IV—DISCUSSION

(a) *Carded Yarns*

Several interesting conclusions can be drawn from a study of Table I. It will be seen that the percentage differences between the calculated and the actual values of lea breaking strength are generally positive when the "lea ratio" is less than 70%, and negative when it is greater than 70%, and that, although in a majority of cases they are under 10%, in some cases they assume very large values. This is true both for carded and combed yarns, and disposes of the possibility of Gregson's method being applicable to *all* types of yarn, as it is seen that in several cases the value of lea strength calculated according to this method, is either very much greater or less than that actually found by experiment. It will be further seen that whereas the percentage differences without applying the correction for different lengths of yarn are generally positive, *i.e.* the calculated value is greater than the observed value, these differences are as often positive as negative when the correction is applied. Furthermore, the magnitude of the differences on the whole is less with than without the correction. These results show that, although the agreement between the values of the calculated and the observed lea strength is far from satisfactory, it has a distinct tendency to improve if allowance is made for the different lengths of yarns employed in the two tests. Again, it will be seen that the disparity between the calculated and the observed values of the lea strength is sometimes very marked in the case of similar yarns spun from duplicate lots of the same cotton. For instance, in the case of the 8'sA yarns spun from duplicate lots of A.19, the percentage difference is +59.8 in one case and -6.6 in the other. As each lea test is the mean of 40 tests, a disagreement of this magnitude cannot be due to experimental or sampling errors but must be attributed to intrinsic differences in the structure of the two yarns. It will also be seen that, allowing for the small variation in actual counts, the 8'sA yarns of A.19 having the higher lea strength gave a lower value for the single thread strength—a feature which is shared by other yarns as well, *e.g.* the two 20's yarns spun from duplicate lots of P. A. 4F. In such cases, which are rather difficult to explain, Gregson's method is bound to break down completely. A possible explanation for this lack of correspondence between the results of the lea and the single thread test may lie in the different treatment to which yarn is subjected in the two tests. In the lea test the average behaviour of 160 threads is observed at a time and, at least in the initial stages of loading, rupture of the relatively weak threads throws greater weight on the remaining threads than their normal share; while in the single thread test each thread is individually examined and its rupture does not affect the preceding or the succeeding lengths of yarn. That the structure of yarn plays an important part in determining the degree of agreement between the calculated and the observed values of lea strength is shown by the following consideration. If we compare the percentage differences for 30's yarns of good quality Indian cottons, Jayawant, Gadag 1, 1027 A.L.F., P. A. 289F, Hagari 1, and Hagari 25, we find that 1027 A.L.F. has given the worst agreement. On calculating the "yarn irregularity" of 30's yarns of these cottons, according to the method described on page 16 of the Technological Bulletin, Series A, No. 21, we notice that this statistic has the highest value for 30's yarns of 1027 A.L.F. We thus find that high "yarn irregularity" is associated with poor agreement between lea strength as actually determined and as calculated from results of the single thread test.

If we compare the trend of values of the "lea ratio" and the percentage differences, we notice the highly interesting fact that in almost all cases in which the lea ratio is either high or low the percentage differences are large, *i.e.* in such cases the agreement between the calculated and the observed values of lea strength is very poor. On the other hand, in almost all cases in which the "lea ratio" lies between 67 and 77 the percentage differences are generally quite small, being of the order of 5, *i.e.* in such cases the agreement between the calculated and the observed lea strength is passable. This will be seen quite clearly from Table III, in which the percentage differences are shown against the corresponding "lea ratios," which have been arranged in

Table III
Lea-ratio and % Difference arranged in Ascending Order of the Lea-ratio
(Carded Yarns)

Counts	Lea Ratio (%)	(%) Difference	Counts	Lea Ratio (%)	(%) Difference	Counts	Lea Ratio (%)	(%) Difference	Counts	Lea Ratio (%)	(%) Difference
8A	39	+59.8	30	65	+3.8	20	70	+2.1	20A	75	-5.5
8B	47	+34.9	26	65	+0.9	20B	70	+1.1	40	75	-8.0
30	54	+25.3	10A	65	-8.3	34	70	+0.8	20A	76	-1.9
30	54	+16.7	30	66	+10.8	16	70	-0.8	20A	77	-1.8
30	55	+22.2	34	66	+7.7	30	70	-2.3	20B	77	-3.3
6	55	+13.6	34	66	+7.3	40	70	-4.0	20	77	-8.2
26	57	+18.2	20A	66	+5.4	20B	71	+4.0	20	78	-3.9
8A	58	-6.6	26	66	-11.1	30	71	-0.2	30	78	-6.7
6	59	-2.8	20	67	+11.9	20	71	-5.0	12	78	-8.3
40	60	+16.6	20	67	+10.3	14	71	-5.9	30	78	-12.3
8	60	+11.2	24B	67	+6.5	20	71	-7.3	10	79	-6.8
24A	61	+13.6	24	67	+4.1	20B	72	+4.2	20B	79	-9.7
26	61	+13.0	34	67	+0.5	20A	72	+1.7	34	79	-10.1
30	61	+8.7	40	67	+0.3	14	72	-0.8	20A	79	-12.6
10	61	+2.6	34	67	-1.1	20	72	-4.5	30	79	-14.1
26	62	+11.3	40	67	-0.2	20B	72	-7.7	30	80	-10.3
24B	63	+15.4	40	68	-0.3	16	73	-2.7	20A	80	-10.4
30	63	+14.6	34	68	-2.6	10B	73	-2.7	20B	81	-4.3
20	63	+13.4	40	68	-2.8	30	73	-3.2	20B	81	-6.6
34	63	+8.5	26	68	+5.5	20	73	-6.0	30	81	-23.0
10A	63	+5.0	20A	69	+7.7	30	73	-7.4	20B	82	-9.9
8B	63	-3.8	8	69	+0.6	20B	74	+0.3	20B	83	-11.9
30	64	+10.6	16	69	-0.3	10	74	-8.9	20A	84	-15.0
30	64	+5.1	14	69	-1.8	40	74	-10.9	12	84	-20.2
20A	64	+4.0	10B	69	-4.5	14	75	+0.9	20	85	-13.2
20B	65	+9.7	20A	70	+3.3	10	75	-0.9	16	85	-16.7
24A	65	+7.3	24	70	-1.8	20A	75	-1.7			
30	65	+6.8	30	70	+2.1	20	75	-2.5			

ascending order of magnitude. It will be noticed that the percentage differences assume low values when the "lea ratios" lie between 67 and 77. It may be mentioned here that in the particular case quoted by Gregson the lea ratio was 79% and hence the good agreement obtained by him is in line with the above conclusion. This is a very important result, as it shows us the limitations of Gregson's method. We see from it that we can expect passably good agreement between the calculated and the observed values of lea strength only in the case of those yarns for which the "lea ratio" lies between the limits mentioned above. It will be seen that so far as prediction of the lea strength is concerned, this conclusion does not take us very far, as, unless the lea test is actually performed, it would not be possible to calculate the "lea ratio"; and, with the completion of the lea test, the need for calculating its probable value

would disappear. It has, however, this practical consequence, that if the results of the single thread test are used as a check upon the lea test results, then we know that the check would be most satisfactory in the case of those yarns for which the "lea ratio" lies between 67 and 77. Subject to this limitation, Gregson's method can be made to serve the useful purpose of checking the results of one test against the other, whenever necessary.

It will also be seen from Table III that yarns spun into the same counts may have widely different "lea ratios." Thus, 30's yarns obtained from different cottons have lea ratios varying from 54 to 81. It is, therefore, totally impossible, in the prediction of lea strength, to go by counts alone; the lea ratio must first be found in any given case, and, if it happens to lie between 67 and 77, the single thread test results may be used as a check against the observed value of lea strength.

(b) **Combed Yarns**

The observations made above with respect to carded yarns also apply to combed yarns. It will, however, be seen that the percentage differences between the calculated and the observed values of lea strength do not vary so radically for combed yarns spun from duplicate lots of the same cotton as was the case with carded yarns. This, in all probability, is due to the more regular and even structure of the combed yarns. Furthermore, we notice that for combed yarns, the percentage differences are more frequently positive than negative, showing that for these yarns the values of lea strength, calculated according to Gregson's method, are frequently higher than those actually given by experiment. Again, it will be seen that, as in the case of carded yarns, the percentage differences assume their lowest values when lea ratios lie between 67 and 77. This means that for combed yarns, too, Gregson's method is capable of application as a means of checking the observed lea strength, only if the lea ratio lies between the limits mentioned above. This feature is brought out clearly in Table IV, in which the percentage differences are given against the corresponding lea ratios, which have been arranged in ascending order of magnitude.

Table IV
Lea-ratio and % Difference arranged in Ascending Order of the Lea-ratio
(Combed Yarns)

Counts	Lea Ratio %	% Difference	Counts	Lea Ratio %	% Difference
70	57	+27.6	70	66	+ 3.4
60	59	+ 27.5	60	66	+ 7.3
70	60	+14.9	60	66	+ 9.9
60	61	+13.4	70	66	+14.6
80	61	+14.9	80	67	+ 1.5
60	61	+11.9	50	68	+ 9.5
60	62	+12.3	70	68	- 1.9
60	62	+15.2	70	73	- 5.4
70	62	+22.4	60	74	- 4.6
70	63	+ 7.5	70	74	-10.7
50	63	+11.5	60	75	- 2.6
60	63	+12.4	70	77	- 4.0
50	64	+11.6	70	77	-11.8
50	64	+12.9	60	78	- 5.2
60	65	+ 8.5	70	78	-16.2
50	65	+ 9.6	50	79	-14.3
60	65	+11.5	60	90	-22.6

V—SUMMARY

In *The Textile Weekly* of 8th April 1932, Gregson has suggested a method of predicting the lea breaking strength of a yarn from an analysis of the individual results of its single thread test. As his conclusions were based upon the behaviour of only one yarn, it was not possible for him to infer either the general applicability or the limitations of his method. The present paper describes the results of application of Gregson's method, with the above-mentioned two objects, to 144 carded and combed yarns, spun from standard Indian cottons into counts ranging from 6's to 80's. The following conclusions are derived—

(1) The lea strength, as obtained by Gregson's method, is generally greater than the observed lea strength when the lea ratio

$$\frac{\text{lea strength (lb.)} \times 100}{160 \times \text{mean single thread strength (lb.)}}$$

is less than 70, and less than the observed lea strength when the lea ratio is greater than 70.

(2) The percentage differences between the calculated and the observed lea strengths are comparatively small only if the lea ratio lies between 67 and 77. In almost all other cases the percentage differences are quite large, i.e. Gregson's method breaks down completely.

(3) Even when the lea ratio lies between 67 and 77 the agreement between the calculated and the observed lea strength is not always very good—a discrepancy of 5% is quite common, of 10% not uncommon.

(4) There is apparently no relation between the counts and "lea ratio," so that unless a lea test is actually performed it is not possible to foretell the "lea ratio" of a yarn.

(5) In view of the above conclusions, the only practical application of Gregson's method is that, when both tests are performed, it can serve as a check upon the lea test results in those cases in which the lea ratio lies between 67 and 77. It cannot be used to predict the lea strength in any and every case.

(6) Even in the case of similar yarns, spun from duplicate lots of the same cotton, the percentage differences between the calculated and the observed lea strength may sometimes assume large values. This is probably due to the different degrees of irregularities in the structure of yarn which are revealed more minutely by the single thread test than by the lea test.

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5—PROPERTIES OF RUBBER THREADS USED IN TEXTILES

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Large quantities of rubber thread are being used in woven and knitted textiles and braided goods, and manufacturers have been seeking more information on its properties and uses. Great improvement has been effected in the properties of such materials, particularly in the direction of regularity of diameter and resistance to deterioration in washing and finishing. Progress has also been made in the direction of producing finer threads than ever before, so that they can be employed in lighter weight articles. The use of this material in garments is on the increase, and in the following paper methods of gauging the size of these threads is given along with an account of present methods adopted for tensile and elongation tests. Regularity of diameter tests and those for washing are also given along with an account of the covering process.

The following are details of a number of tests made on a range of counts of square-cut rubber thread under the standard conditions described. The machine employed is the Goodbrand vertical single thread testing machine, and the tests were made at 67° relative humidity and 63° Fahrenheit. The test length taken is one inch in length, and the grips are provided with rubber ring crashers between which the thread is suspended during the test to ensure that no slippage occurs. The jaw is adjusted to travel downwards at the speed of twelve inches per minute, this being generally adopted in tests similarly made on wool or cotton yarns. It is important that the thread should be taut before the test is applied and hand tension is specially unreliable as the stretch of material is easily affected. A weight of seven grammes has been found satisfactory to append to the thread before securing the lower jaw. Certain firms use a longer test length of three inches, and a weight of several ounces to tighten the thread previous to testing, but this is bound to affect the results appreciably, particularly in the finer counts of thread. This method involves the use of a much longer plunger tube than normal and Fig. 1 illustrates a Goodbrand machine, constructed to take test lengths of more than one inch.

**Test 1—32s square thread
(A) ($\frac{1}{16}$ inch on the square)
1 inch test length**

Breaking load	Extension
oz.	in.
19	8.6
23	8.2
25	7.7
17.5	6.6
25	7.4
22	7.3
23	8.1
24.5	8.0
20	6.9
16.5	6.4

Mean 21.5

7.52

**Test 2—32s square
thread (B)**

Breaking load	Extension
oz.	in.
20	7.7
17	7.2
16	6.9
18.5	7.9
13	6.2
19.5	7.0
14	7.3
24	8.8
17	7.2
24	8.2

Mean 18.3

7.4

**Test 3—36s square
thread (A)**

Breaking load	Extension
oz.	in.
17	7.4
21	8.1
17	6.7
15	7.1
19.5	8.2
24.5	9.2
25	8.2
23	7.7
18	6.8
26	8.7

Mean 20.6

7.8

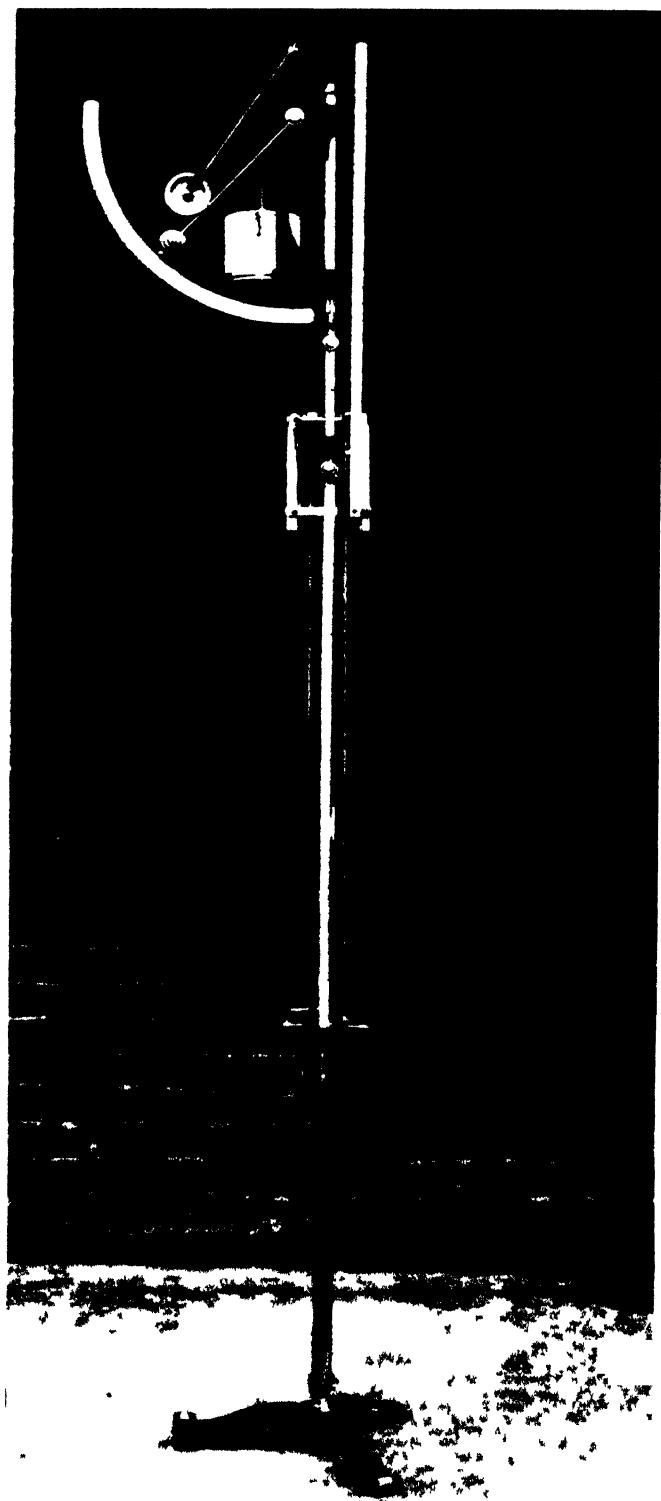


FIG 1

Test 4—36s square thread (B)		Test 5—40s square thread (A)		Test 6—40s square thread (B)	
Breaking load	Extension	Breaking load	Extension	Breaking load	Extension
oz	in	oz	in	oz	in
14.5	7.7	19	6.4	13	7.3
18.5	7.4	18	7.3	14	6.7
24.5	9.5	14	7.3	15.5	7.3
16.5	6.9	20	7.5	19.5	7.6
16.5	7.3	26	8.6	14	8.2
25	8.5	18.5	7.1	16.5	7.5
13	6.6	22.5	7.9	21.5	7.5
19	7.9	21	7.4	20	7.7
15	6.9	22	7.9	21	7.7
13.5	7.4	18.5	7.4	16	7.2
Mean 17.6	7.6	Mean 19.9	7.48	Mean 17.1	7.47

Test 7—44s square thread		Test 8—50s square thread		Test 9—56s square thread	
Breaking load	Extension	Breaking load	Extension	Breaking load	Extension
oz	in	oz	in	oz	in
13	6.6	11.5	6.7	14	7.4
17.5	7.2	13	6.4	12	6.2
11.5	6.1	9.5	6.1	11	5.9
20	7.6	9.5	6.1	10.5	7.2
18	7.8	12	7.3	13	6.7
18	7.8	8	6.0	11.5	7.0
17	8.3	14	6.7	12	6.0
18	7.3	12	6.0	10	5.8
17	7.1	10.5	6.6	9	5.4
18	7.6	15	6.9	9	5.6
Mean 16.8	7.34	Mean 11.5	6.48	Mean 11.2	6.32

Test 10—80s square thread		Test 11—80/100 = $\frac{1}{4}$ × $\frac{1}{100}$ inch oblong	
Breaking load	Extension	Breaking load	Extension
oz	in	oz	in
6.2	6.7	6.6	4.1
5.2	4.9	5.3	2.6
5.2	4.0	6.5	2.8
4.5	8.1	5.1	3.4
8.0	8.4	5.8	2.5
7.7	3.9	6.5	2.5
7.7	3.6	5.7	2.6
6.9	5.1	5.3	2.4
4.8	3.6	5.4	3.4
6.6	6.8	4.5	5.4
Mean 6.28	5.5	Mean 5.6	3.17

These tests reveal the normal deviations from the mean which may be expected in commercial types of rubber thread. At present no general standards of tolerance are recognised, but from experience the maker rejects those showing wide limits. In Test 1 with a mean breaking load of 20.6 oz., the highest result is 25 and the lowest 15, and it is for the user to determine whether threads as low as 15 oz. are likely to prove satisfactory in use. From 32s to 44s the elongation figures are regular about 750 per cent. In the finer counts, the elongation diminishes, fine thread having only 317% extension. It will be noted also that a given count of thread may show a variation in breaking load according as it is soft or hard, but given any particular grade the breaking load should vary according to the square of the cross sectional area.

This principle finds official recognition in the standard system adopted by the makers of such threads in what they term the tension test. The standard length adopted is six inches of thread, this being placed in a fixed grip vertically. The test consists in attaching a weight to the test length and noting the length to which this piece extends. The weight to be applied is calculated on the basis of 228 pounds per square inch; 20s thread for example is $\frac{1}{32}$ inch square, and the weight for this is calculated by proportion*.

When these weights are hung on to the six inch piece, brown rubber threads are expected to move down to between 28"–31" to be passed as satisfactory. The standards of white rubber round threads are about 25% lower than those just mentioned—

22 inches—25 inches for 24s counts and coarser,
20 inches—25 inches for 26s counts and finer.

The test is performed on a vertical scale, marked off in inches and the record is taken at the first dip. If the weight is allowed to hang for some time, there may be a further creeping downwards, indicating that the elastic property is being influenced.

Table I records tension tests made on the range of square cut threads already dealt with in Tests I and II.

Table I

Counts of rubber thread	Length tested in.	Weight attached oz.	Extended length in.	Percentage extension
32 (A) ...	6	3.56	27.6	360
32 (B) ...	6	3.56	30.6	410
36 (A) ...	6	2.76	28.5	390
36 (B) ...	6	2.76	28.2	370
37 × 36† ...	6	2.74	25.2	320
40 (A) ...	6	2.28	24.0	300
40 (B) ...	6	2.28	30.0	400
44 ...	6	1.88	28.8	380
50 ...	6	1.46	30.0	400
56 ...	6	1.16	28.2	370
80 ...	6	.57	31.8	430
100 × 80† ...	6	.45	25.8	330

ROUND RUBBER THREADS

There is now extended interest in rubber threads which are produced by extruding rubber latex through circular capillary tubes into a coagulating solution which solidifies the rubber prior to vulcanising. The square thread is limited in length to about 70 yards, but the round thread can be made in any required hank length to suit such operations as warping or winding,

*A yarn with a square of $\frac{1}{32}$ inch has an area of $(\frac{1}{32})^2 = \frac{1}{1024}$ but 1 sq. inch = 228 lb. $\therefore 228 \times 16 = 9.12$ oz. weight. Similarly for a yarn $\frac{1}{64}$ inch square = $\frac{1}{4096}$ sq. in.

$$\frac{228 \times 16}{400} = 9.12 \text{ oz.} \quad \frac{228 \times 16}{1600} = 2.28 \text{ oz.}$$

A list of standard weights for a range of square thread is given herewith, calculated on the method given above—

in.	oz.	in.	oz.
$\frac{1}{32}$	9.12	$\frac{1}{64}$	1.46
$\frac{1}{64}$	5.83	$\frac{1}{128}$	1.0
$\frac{1}{128}$	4.05	$\frac{1}{256}$	.57
$\frac{1}{256}$	2.28	$\frac{1}{512}$	.36

†It is sometimes found that the thread is cut slightly oblong and this is indicated in two examples, 37 × 36 meaning $\frac{1}{32}$ in. × $\frac{1}{36}$ in. and 100 × 80 = $\frac{1}{16}$ in. × $\frac{1}{80}$ in.

with consequent reduction in the number of knots or joins. A new method* of numbering such threads has been fixed where one figure indicates the diameter of the circle of the round thread and side by side is given the equivalent counts in square thread. The following series of tests has been made on a representative range of such round latex threads.

Test 12—20/22 6		Test 13—32/36 16		Test 14—36/40 6	
OZ	IN.	OZ	IN.	OZ	IN.
54.4	9.4	40.0	7.2	20.0	5.6
67.3	8.5	34.4	7.4	22.4	7.8
65.6	9.2	41.6	8.2	19.2	6.0
60.0	7.9	35.3	8.0	25.1	6.75
60.0	8.0	34.8	8.1	25.6	7.75
57.6	8.25	33.6	8.25	20.5	5.5
60.8	8.1	32.8	7.8	24.8	7.5
53.3	7.5	34.4	8.0	21.6	7.0
64.0	8.5	32.0	8.8	24.0	8.0
68.8	8.9	32.0	7.5	22.4	8.75
Mean 61.18	8.42	Mean 35.09	7.92	Mean 22.56	7.06

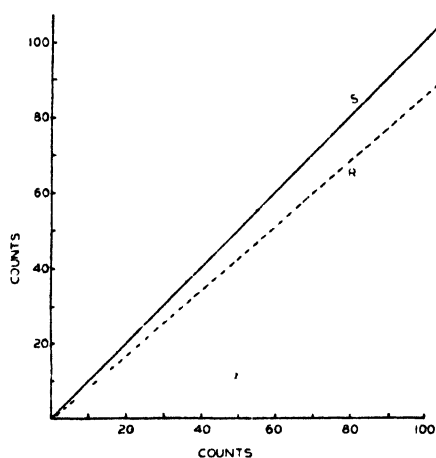


FIG. 2

* The Conversion factor for this is derived as follows—

$$\text{Ratio—} \frac{\text{square}}{\text{circle}} = \frac{\frac{d^2}{\pi d^2}}{\frac{4d^2}{\pi d^2}} = \frac{2}{\sqrt{3 \cdot 1417}} = \frac{2}{1.77} = 1.13$$

Thus where R = round thread, and S = square thread

$$\frac{S}{R} = 1.13, \text{ and } \frac{R}{S} = \frac{1}{1.13}$$

The counts may also be determined by using the graph given in Fig 2, where the square thread system is indicated by the straight line S, and the corresponding round thread counts by the line R, equivalents can be quickly read off by moving from one line to another, horizontally or vertically as required

Examples—(a) To find the equivalent round thread counts of 22s square thread—

$$\frac{22}{R} = 1.13$$

$$R = 22 \div 1.13 = 19.5 = 20\text{s round thread}$$

(b) Find the square thread counts equivalent to 36s round thread—

$$\frac{36}{S} = \frac{1}{1.13}$$

$$S = 36 \times 1.13 = 40.68 = 40\text{s square thread}$$

Test 15—40/45.2		Test 16—44/49.7		Test 17—64/72.3	
oz.	in.	oz.	in.	oz.	in.
25.6	8.75	14	7.0	8.5	3.2
24.0	6.25	14	6.1	9.0	6.25
19.2	5.75	14	5.6	10.1	5.5
16.0	6.4	17	4.0	9.0	4.75
20.5	6.1	17.5	6.5	7.0	4.8
20.8	7.15	15	6.75	12.0	4.8
20.0	7.9	15	5.8	12.0	5.25
24.8	7.75	18	8.0	9.0	4.25
20.5	8.6	17	5.0	10.0	6.5
22.4	8.0	16.8	6.8	11.0	4.5
Mean 21.38	7.26	Mean 15.83	6.15	Mean 9.76	4.98
Test 18—100/113					
oz.	in.				
3.25	7.5				
2.8	7.1				
2.6	6.75				
2.8	5.0				
2.8	5.0				
2.3	4.5				
3.0	5.0				
2.75	6.0				
2.25	5.0				
2.0	5.1				
Mean 2.75	5.7				

These results when compared with those of equivalent counts in the square thread, show that the round latex type has an appreciably higher breaking load, whilst the elongation is about the same in the two types of threads. In general, the elongation shows a reduction as the finer counts are approached. The mean strength values of the square thread series marked

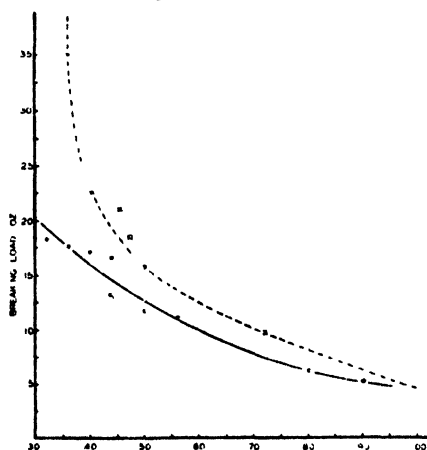


FIG. 3

S, and those of the round latex series R, are given herewith in Fig. 3 where the counts are shown as the ordinate and the resulting breaking loads on the abscissæ. These curves are obviously incomplete as they are based on too few numerical tests, but they indicate how a user of such materials may for each type of rubber thread construct a curve which will serve to indicate the breaking loads to be expected. Should threads fail to reach those standards, the delivery would be rejected as being unsuitable for the user's requirements.

Table II records a series of tension tests on round latex threads similar to those made on the square threads and recorded in Table I.

Table II

Round diameters	Equivalent square counts		Length tested	Weight attached	Extended length	Percentage extension
			in.	oz.	in.	
20	22.6	...	6	9.2	18.5	208
32	36.16	...	6	3.54	25.5	325
36	40.6	...	6	2.8	24	300
40	45.2	...	6	2.26	25	316
44	49.7	...	6	1.88	27	350
64	72.3	...	6	.89	21	250
100	113	...	6	.36	28.5	370

A comparison with the tension tests made on the square threads show that they are more extensible than the round latex types, but weaker, especially in counts below 40s.

In the case of rubber threads, the autographic device for producing the stress-strain diagram is specially useful. This diagram indicates the behaviour of the thread whilst it is being tested, and also provides a record of both breaking load and elongation which can be filed and used as a check on numerical records. It indicates for example certain weaknesses in a thread due to air bubbles and other causes; at such points the thread will attenuate with extreme rapidity, without taking any further load and it is important that such defects should be revealed by testing. A typical curve is given in Fig. 4.

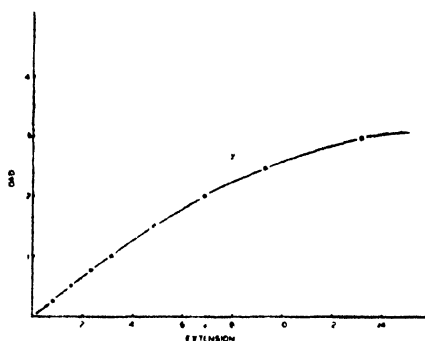


FIG. 4

TESTS FOR COUNTS OF RUBBER THREADS

This is essential for many purposes, particularly when the descriptive labels have been lost or misplaced as it enables the materials to be re-sorted. Further than this, it is essential to know that the strands are of the thickness indicated by the counts. This is another way of stating that the diameter of the threads has to be ascertained, and the usual methods of doing this can be adapted without the dangers attendant on similar measurements of fibrous yarns such as cotton or wool. The simplest method is to use a metal cylinder of .3 inch in diameter with a smooth surface round which the threads can be coiled. In dealing with round threads this method is very satisfactory, as the succeeding coils have just to touch each other and the number of such coils per inch represent the counts. For square threads, it is more difficult to wrap the threads as they tend to lie on their corners during the process. For such materials, the ordinary micrometer screw of

the engineer can be used, the strand of rubber being passed through the space until the correct diameter is obtained. With some practice, this method is quite reliable for rapid results in a works. The usual micrometer eyepiece attachment to the microscope can also be used if greater accuracy is essential, and this method also allows of passing the thread through to test for regularity of diameter or thickness which is also important as it affects the uniformity of the resultant covered yarn. Examination of specimens produced by reliable firms affords evidence of the high standard of accuracy reached by makers of rubber thread, and the following results are quoted from an examination of a number of commercial samples.

Reputed counts		Coils per inch		Reputed counts		Coils per inch
28s	...	28	..	40	...	40
36	...	38	...	44	..	48
40	..	38	..	48	...	48
40	...	39	..	80	...	84

In wrapping the thread round the cylinder, the material should be quite free from strain but in contact with the cylinder surface. Using the micrometer eyepiece, results can be obtained of the greatest accuracy. Then, knowing the exact diameter of the thread and hence the area of the cross section and the specific gravity, the weight of any length of the thread can be accurately determined. In the case of square thread it is essential to make two measurements. If the square has sides a, b, c, and d, one measurement for a and c and a second measurement for b and d would suffice. The following table gives results obtained from a commercial set of square threads which may be regarded as typical.

Reputed counts	Actual counts	Reputed counts	Actual counts
inch	inch	inch	inch
$\frac{1}{32} \times \frac{1}{32}$	$\frac{1}{31.1} \times \frac{1}{27.1}$	$\frac{1}{50} \times \frac{1}{50}$	$\frac{1}{50.4} \times \frac{1}{45.3}$
$\frac{1}{36} \times \frac{1}{36}$	$\frac{1}{35.4} \times \frac{1}{32.6}$	$\frac{1}{56} \times \frac{1}{56}$	$\frac{1}{54.2} \times \frac{1}{48}$
$\frac{1}{37} \times \frac{1}{36}$	$\frac{1}{37.0} \times \frac{1}{35.4}$	$\frac{1}{80} \times \frac{1}{80}$	$\frac{1}{81.5} \times \frac{1}{62.6}$
$\frac{1}{40} \times \frac{1}{40}$	$\frac{1}{45.2} \times \frac{1}{42.8}$	$\frac{1}{100} \times \frac{1}{80}$	$\frac{1}{101.5} \times \frac{1}{81.5}$
$\frac{1}{44} \times \frac{1}{44}$	$\frac{1}{40.7} \times \frac{1}{40.7}$		

WEIGHT/LENGTH OF RUBBER THREADS

This is an important aspect of the material as it has specific connection with the weight of the goods and the vital question of costing. It is also most important in connection with calculations on the resultant counts of the thread when it is finally covered with the usual textile yarns of wool, cotton, silk, or rayon. Given the specific gravity of any particular kind of thread, the weight of any given volume or length can be definitely obtained by calculation as follows. The specific gravity of latex round thread being given as 0.975, the weight in ounces of 100 yards of 64s round thread, for example, can be determined* to be 0.389 ozs.

$$\text{*Volume of 100 yds of 64s} = \frac{100 \times 36 \times \pi}{4 \times 64 \times 64} = \text{cu. inches}$$

$$\text{Specific gravity} = 0.975, \text{ and therefore the volume of an equal weight of water} \\ = \frac{100 \times 36 \times \pi \times 0.975}{4 \times 64 \times 64} \text{ cu. inches.}$$

$$\text{1 cu. inch of water weighs .579 ozs., therefore the weight of the above volume} \\ = \frac{100 \times 36 \times \pi \times 0.975 \times 0.579}{4 \times 64 \times 64} \text{ (1) } = 0.389 \text{ ozs.}$$

The utility of calculating such weights will be apparent and given the specific gravity, for any range of counts, the weight for any standard length in a range of counts can be quickly derived. The weights in other counts can be deduced by proportion since the weight varies directly with the cross sectional area of the thread.

From the formula (i), a constant can be derived which may be used for any other counts of rubber having the same specific gravity. In calculating the weight for counts other than 64s, all factors will remain the same except $(64)^2$, that is, the constant will only require to be divided by the square of the new counts to give the weight of 100 yards of that count, i.e. $\frac{K}{C^2} = W$.

$$\frac{100 \times 36 \times \pi \times 0.975 \times 0.579}{4} \text{ (ii) } = 1593.3 = K$$

This constant can now be used to find corresponding weights in ounces per 100 yards of other counts thus—

$$20s = \frac{1593.3}{20 \times 20} = 3.983 \text{ oz. per 100 yards.}$$

This method can be used to check the testing of counts and delivery weights, and may serve as a useful guide in determining whether there is excess of moisture and other deposits in any delivery of rubber thread. As illustrations may be given, a series of counts of round latex thread where actual weighings have been made to ascertain the weight of 100 yards of each counts. These are exhibited in Table III.

Table III

Counts of Thread		Weight of 100 yds. (by weighing)		Weight per formula $\frac{K}{C^2} = K - 1593.3$	
		oz.		oz.	
20s	...	4.05	...	3.98	
32	...	1.52	...	1.44	
36	...	1.27	...	1.23	
40	...	1.22	...	1.00	
44	...	.772	...	.82	
64	...	.425	...	.39	

For comparison a number of weighings of a commercial range of square cut threads are given with comparative counts in the skein yarn numbering system, i.e. counts based on the number of 256 yd. hanks per lb.

Counts of square cut thread		oz. per 100 yds.		Equivalent skein counts skeins	
32 (A)	...	1.94	...	3.2	
32 (B)	...	2.12	...	3.0	
36 (A)	...	1.54	...	4.06	
36 (B)	...	1.61	...	4.0	
40 (A)	...	1.12	...	5.58	
40 (B)	...	1.26	...	5.0	
44	...	1.06	...	6.0	
50	...	0.75	...	8.3	
56	...	0.72	...	8.7	
80	...	0.33	...	18.0	

Test for Washing

In recent seasons, the range of usefulness of rubber thread has considerably extended, owing to the progress made in rendering it immune from damage in washing, a point which is vital to its success in under-garments which require to be regularly laundered. Certain varieties are now guaranteed

to be boil-proof as they can be subjected to prolonged boiling without deterioration. To test this point, the material is washed a number of times to represent laundering conditions, a simple formula being to use 5% soap flakes dissolved in water, heated to 160° F. The rubber thread is then rubbed, rinsed off and allowed to dry. Two results of this test made eight times in succession on the sample are given herewith; the thread is tested before washing, and then after eight washings and dryings as already indicated.

Test 19—50s counts square white rubber thread. 1" test length

Before washing test				After washing			
Breaking load		Extension		Breaking load		Extension	
oz.		in.		oz.		in.	
10.3	...	5.75	...	14.2	...	6.6	...
11.2	...	5.75	...	7.5	...	5.4	...
6.4	...	5.25	...	15.7	...	5.25	...
13.0	...	6.32	...	9.8	...	5.25	...
11.6	...	4.5	...	13.7	...	7	...
12.3	...	6.12	...	10.1	...	6.12	...
15.8	...	6.4	...	10.3	...	6	...
18.5	...	7.5	...	17.2	...	7.4	...
14.7	...	6.4	...	18.7	...	7.25	...
19.0	...	7.5	...	16.6	...	6.6	...
<hr/>				<hr/>			
Mean 13.28	...	6.15	...	Mean 13.38	...	6.28	...

Test 20—72s counts square grey rubber thread. 1" test length

Before washing				After washing			
Breaking load		Extension		Breaking load		Extension	
oz.		in.		oz.		in.	
11.9	...	8	...	9.0	...	7.4	...
8.9	...	7.4	...	8.0	...	7.25	...
11.0	...	7.75	...	8.8	...	7.0	...
10.6	...	7.75	...	8.7	...	7.5	...
10.8	...	7.75	...	9.3	...	7.0	...
10.2	...	6.12	...	8.7	...	7.0	...
10.6	...	7.0	...	7.6	...	6.0	...
10.7	...	7.75	...	8.8	...	6.25	...
10.8	...	7.5	...	8.0	...	6.25	...
9.9	...	8.25	...	9.9	...	7.0	...
<hr/>				<hr/>			
Mean 10.54	...	7.52	...	Mean 8.68	...	6.86	...

The results of the first series on the 50s counts indicate that no damage has been done by the eight washings and dryings, but in the finer 72s counts there is an appreciable reduction in the breaking load. To obtain results more reliable, a larger number of tests should be taken, but these will serve to illustrate the method of making this most important test.

THE COVERED RUBBER THREAD

Fig. 5 gives a photo-micrograph of a typical covered rubber thread, the centre-core marked A being cut square thread. The first wrapping of yarn is shown unfolded at B, which consists of two threads twisted or coiled round the core with twist towards the right; over these threads and twisted in the opposite direction (towards the left) are shown other two threads unfolded at C. During this process the centre rubber thread is elongated to twice or more its normal length and the covering strands are piled closely together so that the centre thread will remain permanently in its stretched condition, this being a most important factor in the grip exerted by such yarns during their use in textiles. The covering threads coiled in opposite directions also serve to obscure the rubber core as the brown or bluish shade

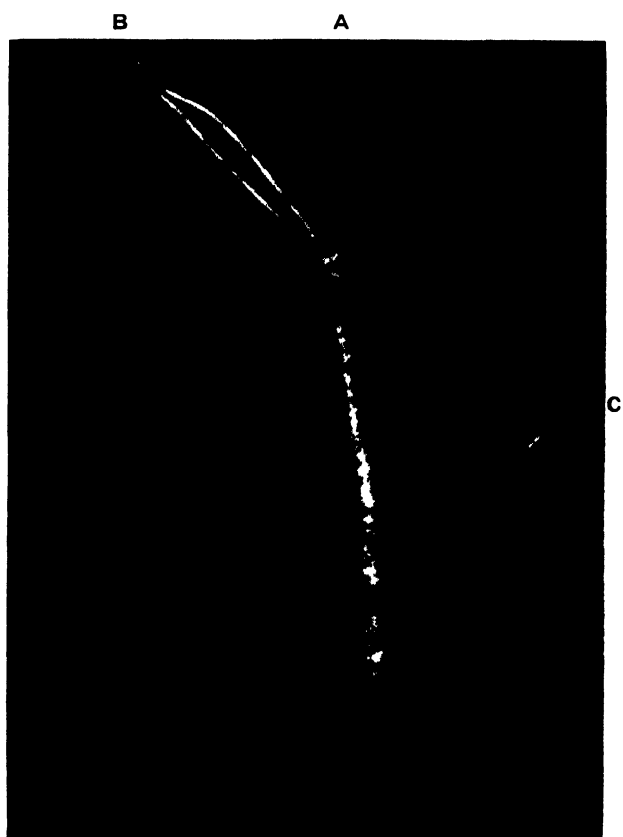


FIG. 5

showing through would detract from the appearance of the goods. Typical textile covering yarns are two ends of 100's single cotton counts for the under threads, and two-ends of the same counts for the upper threads. Opportunity is often taken to have a thinner under thread of cheaper yarn topped with rayon or silk, say two threads of 80s cotton with four threads of 150 denier rayon on top. Covering may also be made in woollen threads if the yarns have to be used in woollen fabrics so that they will dye an equal shade.

Table IV gives the result of a series of tests on 28s to 48s square thread, covered after the usual commercial manner. Ten tests at breaking load and elongation at break have been made on each.

Table IV

	28s Covered		26s Covered		40s Covered		44s Covered		46s Covered		48s Covered	
	oz.	in.	oz.	in.	oz.	in.	oz.	in.	oz.	in.	oz.	in.
1	66	5.4	60	10.25	40	7.25	32	13.0	32	6.38	40	6.0
2	80	6.5	52	9.5	40	6.62	44	12.5	48	6.38	38	3.5
3	83	7.5	64	9.0	48	5.25	32	10.25	52	7.25	43	4.0
4	80	6.0	56	8.5	48	7.25	40	9.62	52	7.25	44	4.25
5	83	7.5	52	9.0	40	6.38	40	9.0	32	6.38	43	3.62
6	83	7.5	52	9.0	40	6.38	44	12.5	48	6.38	43	4.72
7	80	6.0	56	8.5	48	7.25	32	13.0	40	7.0	41.5	4.5
8	66	5.4	64	9.0	48	5.25	40	9.62	52	7.0	44.5	3.25
9	80	6.5	52	9.5	40	5.62	32	10.25	40	7.0	43	5.37
10	83	7.5	60	10.25	40	7.25	40	9.0	52	7.0	48	4.5
Mean	80.4	6.58	56.8	9.25	43.2	6.45	37.6	10.87	44.8	6.8	42.8	4.37

The counts above referred to are, of course, the dimensions of the square 28s= $1/28$ inch square. On comparing these results of textile covered threads with those of the uncovered rubber threads previously given, evidence is afforded of (a) the increase in breaking load produced by the covering yarns and (b) the restriction placed on the elongation by the textile yarns.

Acknowledgment is made of the valuable assistance rendered by Mr. G. H. Buckley, F.T.I., and Mr. C. H. Edwards, M.A., A.T.I., of the University College, Nottingham, in the preparation of these results.

Received 9/7/32

6—"MEASUREMENT OF FIBRE AND YARN DIAMETERS BY DIFFRACTION METHOD"

To the Editor.

Sir—In the course of recent measurements with the instrument described in my paper under the above title, published in the *Journal of the Textile Institute* (1932, 23, T223), some discrepancy was found in some samples of cotton fibre between the diameters given by the diffraction method and by the microscope. It has been found, as a result of an investigation of this point, that in some circumstances a slight modification is necessary in the method previously proposed for using the instrument.

In the work previously described, comparison of diameters given by the diffraction method and by the microscope was only carried out in the case of wires over a range of diameters, 0.05–0.12 mm. The results by two methods of setting (Fig. 6, p. T230) appeared very satisfactory, as also did other check tests carried out by measurements with flax fibre strands, which were also all over 0.05 mm. diameter. Owing to the discrepancy which was found in some cotton of about 0.02 mm. diameter, comparisons of diameter by the diffraction method and the microscope, have now been made with widely varying materials over a much greater range of diameters. In the diffraction method, measurements were made using the first narrow bright band for which a value of $n=0.61$ was found previously, and in some cases also the first dark band ($n=1$), for determining the correct separation of the slits. The results are given in Table I.

Table I
Average Diameter in mm.

Material	Microscope	Diffraction Method		Correct Value of n for Bright Band
		Bright Band $n=0.61$	Dark Band $n=1$	
Fibre—Mercerised Cotton ...	0.0139	0.0241	—	0.352
Cotton Sakel ...	0.0161	0.0256	—	0.384
Glass Wool ...	0.0211	0.0304	—	0.423
Artificial Silk ...	0.0262	0.0324	—	0.494
Flax ...	0.0220	0.0294	—	0.458
	0.0272	0.0338	—	0.491
	0.0324	0.0379	—	0.521
	0.0366	0.0410	—	0.545
	0.0400	0.0440	—	0.554
	0.0433	0.0450	—	0.587
	0.0492	0.0490	—	0.61
	0.0496	0.0505	—	0.60
Wires 1	0.0234	0.0304	0.0215	0.47
2	0.0277	0.0349	0.0293	0.49
3	0.0373	0.0400	0.0370	0.568
4	0.0490	0.0490	0.0475	0.61
5	0.0676	0.0670	0.0660	0.615

It will be seen that, using the diffraction method and the first dark band, the agreement with diameters measured by the microscope is fairly close, but using the diffraction method and the bright band, $n=0.61$, agreement is only obtained when the diameter approaches 0.06 mm. In the last column figures are given, which are values of n for the first bright band required to obtain the correct diameter by the diffraction method using this setting. These values are shown graphically in Fig. 1, plotted against the actual diameter measured by the microscope; the points lie close to a smooth curve which approaches the value $n=0.61$, as previously found, at a diameter of about

0.06 mm. No distinction can be drawn between the results from the wires and fibres.

It was pointed out in the original paper that the first bright band ($n=0.61$) is not, whilst the dark band ($n=1$) is, part of the primary diffraction spectrum. This must account for the anomalous behaviour of this first bright band for fibres of very small diameters. The effect cannot be due to refraction of light, since the same behaviour is obtained with these very different materials. In view of the results obtained, modification of the instrument to use the first dark band or the first bright diffraction band was reconsidered. For this purpose it would be necessary to use a wider slit (over 1 mm.), so that

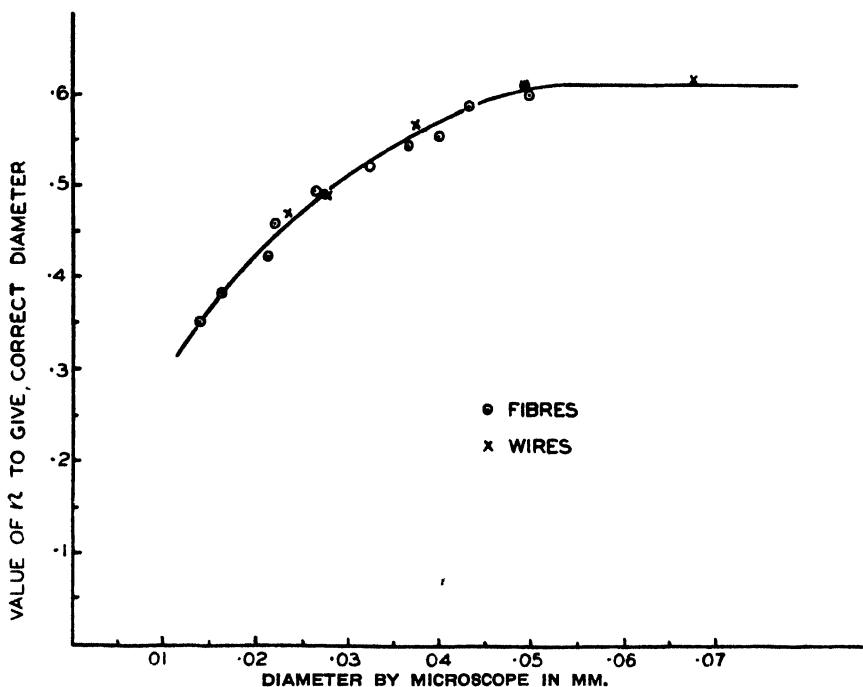


FIG. 1

the first narrow bright band would not be visible. In these circumstances, there is so much diffuse light as to make the diffraction bands appear faint and indistinct and it is very difficult to distinguish clearly the first dark band, especially with a sample in which the diameters are not uniform. Even under the most favourable conditions, the dark band is not well defined, and it is not very suitable as a means of setting. On the other hand, the first bright band using a narrow slit is bright, narrow, sharply defined, and easily distinguishable, and so the setting by alignment of the bands in the top and bottom spectra can be made with very fair accuracy.

The previously expressed opinion as to the advantages of this method of using the instrument is therefore adhered to, and in order to obtain correct results with materials of very small diameters, the apparent diameter, as previously described, must be multiplied by a correction factor to be obtained from a chart which can be constructed, giving the correction factor plotted against the apparent diameter. This correction factor is obtained from the figures in the last column of Table I, by dividing the correct value of n

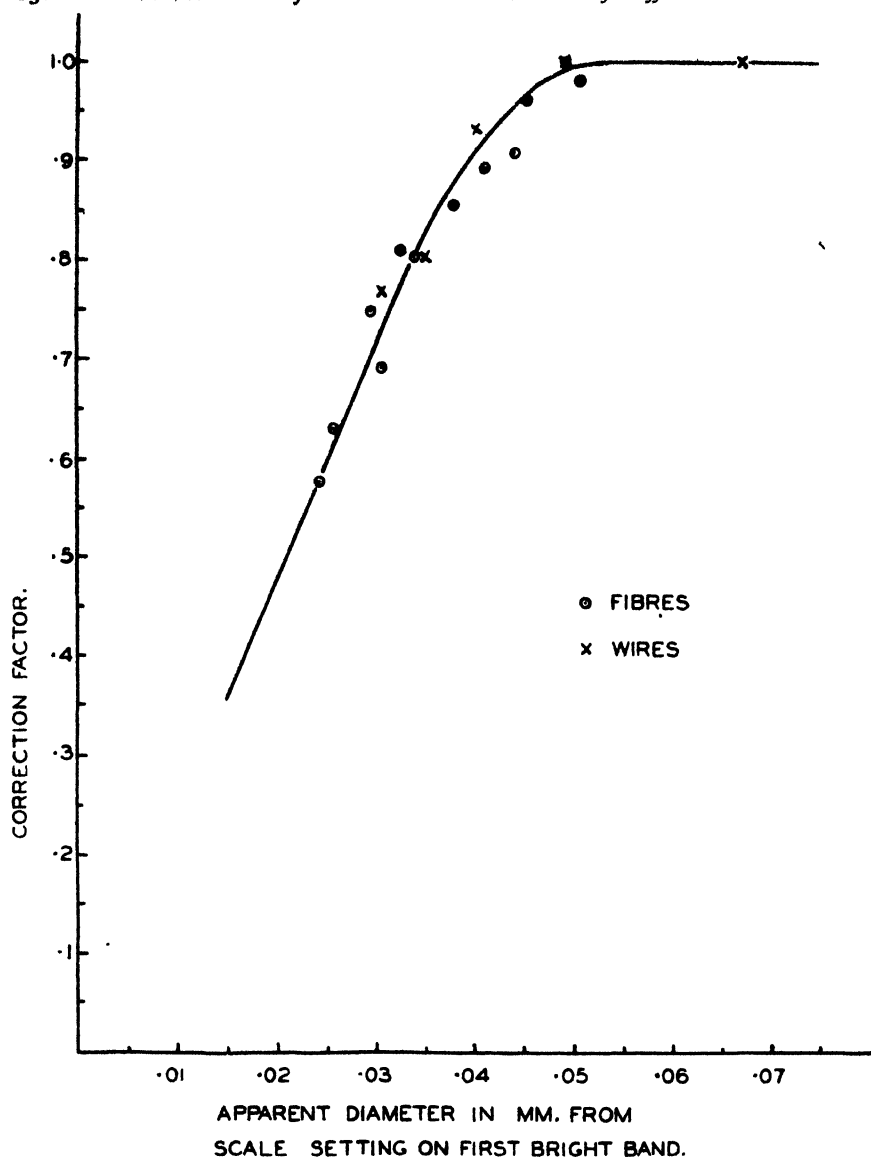


FIG. 2

by 0.61, and is shown graphically in Fig. 2. In practice, therefore, the instrument would be calibrated as previously described, with wires of known diameter to give the relation $D_a = K/S$

where D_a is the apparent diameter, S =scale setting, and K a constant. Then the real diameter $D = cD_a$, where c is the correction factor appropriate to the value of D_a read off from the chart supplied (as Fig. 2). For values of D over 0.06 mm., $c=1$.

Lambeg
Northern Ireland

Yours faithfully

J. A. MATTHEW

THE JOURNAL OF THE TEXTILE INSTITUTE TRANSACTIONS

7—REPORT TO THE NEW ZEALAND GOVERNMENT ON ENGLISH LEICESTER (38's/42's), ROMNEY (44's/46's), ROMNEY (46's/48's), AND CORRIEDALE (50's/56's) WOOLS

By ALDRFD F. BARKER, M Sc., F.T.I.

(The University of Leeds)

OBJECTS OF THE INVESTIGATION

The evolution of the wool-growing industry in the North Island, N.Z., has followed the line Merino, Lincoln \times Merino (giving rise to the true Corriedale), Romney Marsh \times Lincoln Merino, and a stage has now been reached when the wool grown is predominantly Romney either pure-bred or cross-bred. For many districts in New Zealand the Romney, from total profit points of view—including its prolificness and survival values—seems the most suitable sheep to rear, but, unfortunately, as the Romney breed has more and more dominated, the complaints from the Yorkshire spinners with reference to Romney and Romney-cross wools have increased, and to-day there is an outcry against the deteriorated quality of New Zealand cross-bred wools—particularly those of the Romney type.

It has, therefore, been considered desirable to undertake any and every investigation which is at all likely to throw light upon the reasons for the degeneration in type said to be markedly in evidence by Yorkshire cross-bred spinners. With this object in view, the New Zealand Government have provided two lots of Romney wools, and also a Leicester and a Corriedale wool for comparative purposes, with the object of having these submitted to the normal trade processing in the hope that careful analysis at each stage of this processing may throw light upon the defects said to exist and may ultimately lead to useful advice being given to the New Zealand wool-growers with reference to the selection of Romney and Romney cross-sheep for breeding purposes.

PREVIOUS RESEARCHES

Three noteworthy investigations previous to the present one, have either included Romney wools in their survey or have been based upon Romney wools.

Leeds University Research

The first of these was the investigation conducted by Leeds University in collaboration with the Royal Agricultural Society of England into the manufacturing possibilities of pedigree British wools—among which Romney Marsh wool was, of course, included. The results of this investigation were fully reported in the issues of *The Journal of Textile Science* (1924 and 1925) from which the following particulars are taken.

1—*The Sorted Qualities*—In the following list are given the sorted qualities from Blackface, Lincoln, Romney Marsh, and Southdown wools ascertained by examination of the woolled skins submitted.

Blackface	...	...	Low, 28's, and 32's
Lincoln	...	...	32's, 36's, and 40's
Romney Marsh	...	...	32's, 36's, 40's, 46's Shorts
Southdown	...	...	50's, 56's/58's

From this list it will be noted that while Blackface and Lincoln were sorted into three qualities and Southdown into two qualities, Romney Marsh was sorted into five qualities. That the Romney Marsh sheep does carry a greater variety of wool qualities in its fleece than most English breeds is obvious on inspection of even the best Romney Marsh pedigree flocks.

2—*Fibre Diameters*—The fibre diameters of all the pedigree wools were recorded and the following are useful comparative results.

		Average Dia.		Minimum Dia.		Maximum Dia.
Blackface	...	1/469"	...	1/1312"	...	1/147"
Lincoln	...	1/552"	...	1/875"	...	1/350"
Romney Marsh	...	1/701"	...	1/1500"	...	1/447"
Southdown	...	1/879"	...	1/1500"	...	1/500"

From these figures Romney Marsh wool seems, if anything, to be finer than it ought to be. This is accounted for by the extreme fineness of the fine fibres, these being equal to the finest fibres of Southdown or even of some Merino wool. This peculiarity is nearly always in evidence in Romney Marsh wools and will be referred to later. It would seem probable that owing to the presence of these fine fibres, Romney wools may be classed too high in the scale of wool qualities with a resultant disappointment in spinning results.

The statement is sometimes made that Romney wools thicken at the fibre tips and thus give an inferior "spin." A series of wools was measured with this suggestion in view and gave the following average results.

			Root		Tip
Lincoln	...	...	1/524"	...	1/490"
Wensleydale	...	...	1/737"	...	1/630"
Romney Marsh	...	...	1/667"	...	1/608"

From this list it would appear that all wools are liable to thicken at the tips and that Romney Marsh is better than some and worse than others.

3—*Ratio of Fibre Cross Sectional Area (πr^2) to Fibre Length*—This may be an important consideration, for if the ratio of fibre length to fibre cross sectional area is greater in the Romney Marsh than in other wools, then relatively more breakage (and a worse tearage) and a worse "spin" may be expected. The following list is interesting from this point of view.

			Average Dia.		Average Length		Ratio
Prepared	{ Blackface	...	1/469"	...	11.22"	...	1.31×10^6
	{ Lincoln*	...	1/552"	...	8.05"	...	1.31×10^6
	{ Leicester	...	1/614"	...	12.02"	...	1.58×10^6
Carded	{ Romney Marsh	...	1/701"	...	6.3"	...	1.40×10^6
	{ Southdown	...	1/879"	...	5.67"	...	1.36×10^6

* A short fleece

From these figures it is suggested that with the exception of the Leicester, the Romney Marsh wool is finer in proportion to its length than the other wools, and for equal soundness of staple may be expected to break more frequently in "processing" than the other wools. This suggestion is borne out by the "optimum lengths" given in the South African Report,* which run as follows—

				Diameter	...	Optimum Length	...	Average Length
Prepared	{	Blackface	...	1/450"	...	6"	...	11.22"
		Lincoln	...	1/600"	...	4.6"	...	8.05" *
Carded	{	Romney Marsh	...	1/700"	...	3.9"	...	6.3"
		Southdown	...	1/900"	...	3.1"	...	3.67"

This suggestion is further confirmed by the following "tearage" results in combing—

				Proportion "Top" to "Noil"
Prepared	{	Blackface	...	6 to 1 (double growth)
		Lincoln	...	19.5 to 1
Carded	{	Romney Marsh	...	10.5 to 1
		Southdown	...	7.5 to 1

This abbreviated list, however, hardly conveys the right idea. With the exception of the Southdown, Romney Marsh gives the least satisfactory combing result of all the Demi-lustre and Down wools. The "preparing" process for long and even medium wools is giving way to the "carding" processes even in the case of 44's/46's qualities; this latter needs special care with reference to "length breakage" and Romney wools are probably seriously affected if "carded."

The following list of "Yarn Strengths" seems to indicate that this deduction is true.

				Average Woollen (18" test)	...	Average Worsted (18" test)
Blackface	...	...	...	23.66 ozs.	...	48.65 ozs.
Lincoln	...	...	...	31.49 ozs.	...	61.8 ozs.
Romney Marsh	.	.	.	32.95 ozs.	...	42.5 ozs.
Southdown	...	.	...	18.6 ozs.	...	34.31 ozs.

Of these yarns the Romney Marsh worsted is noticeably weak, thus tending to confirm the suggestion of undue fibre-breakage in processing. This is confirmed by the strength tests of the worsted cloths from the loom.

				Average Strength Warp	...	Average Strength Weft
Blackface	...	...	...	112.62 lb.	...	125.62 lb.
Lincoln	...	...	...	135.32 lb.	...	141.49 lb.
Romney Marsh	.	.	...	101.38 lb.	...	112.62 lb.
Southdown	...	...	...	87 lb.	...	95 lb.

The Southdown record further supports this suggestion that length is an important factor in strength and, consequently, in spinning: Ryeland,

* *Journal of Textile Science*. Vol. III. Nos. 3 and 4.

Oxford, and Suffolk wools being longer than Southdown, but not nearly so long as the Romney, give superior strength results.

Conclusions—From this review it would appear that Romney Marsh (British) wools suffer from containing fine fibres which render them liable to be misjudged as to spinning quality, and, further, being usually somewhat longer than most of the other British wools in proportion to the cross-sectional fibre area, are liable to be broken in the processing and this gives a high proportion of noil and a shorter-fibred top which tends to show a defect in spinning, in yarn strength, and in cloth strength. But generally speaking, English Romney Wools are noted for their “loftiness” and within their limits produce both sound yarns and fabrics.

The Peruvian Report*

An investigation into the development of Peru as a sheep-breeding and wool-growing country included the consideration of some Peruvian crosses. Among these were Nos 3, 4, 7, 8, and 9 half-bred Romney and No. 5 three-quarter-bred Romney (List VII, p 141-142). The following are the diameter frequencies of these wools.

Diameter	(3)	(4)	(5)	(7)	(8)	(9)
1/2200"		18	—	19	20	21
1/1500"		4	34	13	4	—
1/1300"	—	18	45	21	14	11
1/1160"	39	18	73	26	25	23
1/1050"	45	21	41	20	23	25
1/690"	47	19	7	11	13	18
1/880"	43	16	—	9	16	12
1/810"	25	3	—	—	5	7
1/750"	1	1	—	—	—	4
1/700"	—	—	—	—	—	—
Coarser than 1/700"	—	—	—	—	—	—
Average diameter	1/966"	1/1052"	1/1205"	1/1138"	1/1055"	1/1015"

From these figures it will be seen that four out of the six Romney crosses show some remarkably fine fibres as well as fibres of 1/1500 in. This confirms the suggestion that Romneys tend to grow fine fibres among normal fibres. These fine fibres may lead to the misjudging of the quality of Romney wools and thus to criticism based on the failure to spin to the counts which

* “The Prospective Development of Peru as a sheep-breeding and wool-growing Country” Presented to the Peruvian Government in June 1927, by Aldred F. Barber and Colonel Robert J. Stordy

the supposed quality number should readily spin to. It is noteworthy that in none of these wools are to be found the coarse fibres which undoubtedly do too frequently appear in New Zealand bred Romney crosses.

British Wool Research Report (Pub. 115)

The third investigation referred to is that undertaken by the British Wool Research Association and has particular reference to the cross-sectional contour of fibres of Romney, Corriedale, and Romney \times Corriedale wools. This research is fundamentally based on the assumption that wools with a circular cross-sectional diameter will spin better than wools with a non-circular (more or less elliptical) diameter. In view of our present knowledge respecting the effect on spinning of the shape of the cross-sectional areas of fibres it would be wise to accept this suggestion with caution. It is just as likely that the variation in shape of cross-sections is indicative of some other differences to which may be attributable differences in spinning properties, rather than to it being the direct cause of such difference. The following abstract from the Report may usefully be considered here.

“The essential differences in the three fleeces examined for fibre cross-section and contour are as follows---

(1) Whereas the Romney and the Corriedale fleeces are of different qualities in different parts of the fleece, each fleece exhibits a moderately high degree of uniformity of fibre fineness. The relative degrees of this uniformity have been shown above.

(2) The cross-bred fleece shows much less uniformity than the pure-bred fleeces as regards fibre thickness or area of cross-section.

(3) As regards contour, the variability of the cross-bred is much greater than that of the Corriedale, which is uniform, and approximates more closely to the larger variability of the Romney. The Romney influence preponderates in this respect and hence, according to our contention, the spinning power of the fibres will consequently be reduced accordingly.

In conclusion, it is seen from the whole results of the investigation that the contour of the fibres is an important attribute and the findings based upon its investigation in this case are borne out by experience in actual practice.”

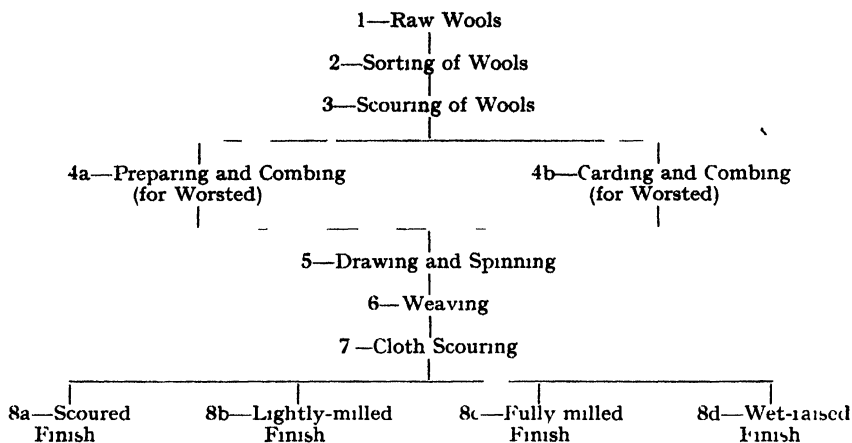
The photo-micrographs given in this report show—

- (a) That in the fine shoulder wool of the Romney some fairly fine fibres appear.
- (b) That in the fine shoulder wool of the Romney \times Corriedale many of these fibres occur.
- (c) That in the coarse rump wool of the Romney \times Corriedale and also in the coarser shoulder wool quite a number of medullated fibres appear.

These observations seem to confirm the deductions made from the records of the foregoing first and second researches with the addition that the cross-sectional shape and contour and the medullation of fibres should be taken into account.

THE INVESTIGATION

In order that exact comparative results may be obtained the following plan of operations has been adopted throughout.



The following are the details of the foregoing processes

(1) *The Raw Wools*—These were received and weighed-in under normal conditions.

(2) *Sorting of the Wools*—These wools were sorted by accredited Bradford sorters (different sorters for each type) under normal trade conditions.

(3) *Scouring of Wools*—The wools were all scoured under similar conditions with reference to (a) strengths of scouring liquors, (b) temperature, and (c) time.

(4a) *Preparing and Combing*—The wools were all passed through seven preparing operations, combed on the Noble comb, and then “finished” through two Finisher Gill boxes to 6 oz. for 10 yds

(4b) *Carding and Combing*—The wools were all passed through the card consisting of opening rollers and two Swifts with four workers and strippers over each Swift, the sliver being 6 oz per 10 yds

Three strong box operations were then given, then the slivers were combed on the Noble comb, and finally passed through two Finisher Gill boxes to give 6 oz. per 10 yds.

(5) *Drawing and Spinning*—All the tops were treated as follows—

Machine	Doub- lings	Drafts	Wts for 40 vds.	Yards per lb	✓Yards per lb — 10%	Turns per foot*	Ratch- ing†
Can Gill ..	3	5	230	44 5	6	—	10'
2-sp Gill	3	5	130	74	7.75	2½	10"
2-sp Drawing	4	5.5	100	103	9	3	10"
4-sp Drawing	4	6	67	154	11	3½	10"
8-sp Finisher	3	6	33 5	315	16	5½	10"
8-sp Reducer	2	6	11.1	935	27	13	10"
12-sp Rover (Spinning)	2	6	3.0	2780	47	5 per 1"	10"

* The 44's prepared Leicester was also treated with different twists, these being 2 17, 1.95, 2.6, 5.25, 8.25, and 5 per in. for the yarn, necessitating a slightly decreased draft to give the required counts of yarn, these all being 4½'s worsted (560 yds. in the hank).

† All the slivers were treated with a 10-in. ratch except the Corriedale which was given an 8-in. ratch.

(6) *Weaving*—The yarns were each made into cloths to the following particulars—warp and weft; all $1/4\frac{1}{2}$'s worsted count; 20 threads and 22 picks per in.; set 36 in. wide + $\frac{1}{2}$ in. lists.

(7) *Cloth Scouring*—The cloths were all scoured under identical conditions in an ordinary Dolly.

(8) *The Normal Scoured Finish, Lightly Milled Finish, Fully Milled Finish, and Raised Finished* were given at the same time to corresponding lengths of each of the qualities of yarns and cloths dealt with.

ANALYSIS OF THE RESULTS

The sorting results—

38's/42's Leicester				46's/48's Romney			
50's Preparing	...	...	8 lb.	50's Carding	...	...	9 lb.
48's Preparing	...	...	12 lb.	48's Preparing	...	...	107 lb.
48's Carding	...	...	16 lb.	48's Carding	...	...	66 lb.
46's Preparing	...	...	54 lb.	46's Preparing	...	...	6 $\frac{1}{2}$ lb.
46's Carding	...	...	39 lb.	46's Carding	...	...	8 $\frac{1}{2}$ lb.
44's Preparing	...	...	60 lb.	40's Preparing	...	...	2 lb.
44's Carding	...	...	8 lb.	40's Carding	...	...	2 $\frac{1}{2}$ lb.
40's Preparing	...	...	13 lb.				
36's Preparing	...	...	$\frac{1}{2}$ lb.				201 $\frac{1}{2}$ lb.
Bits	...	...	$\frac{1}{4}$ lb.				
			210 $\frac{1}{2}$ lb.	Average weight of fleece	...	...	10 lb.
Average weight of fleece	...	...	7 lb.	Lightest	...	...	8 $\frac{1}{2}$ lb.
Lightest	...	...	5 $\frac{1}{2}$ lb.	Heaviest	...	...	11 $\frac{1}{2}$ lb.
Heaviest	...	...	10 $\frac{1}{2}$ lb.				
44's/46's Romney				50's/56's Corriedale			
46's Preparing	...	...	141 $\frac{1}{2}$ lb.	58's Carding	...	...	50 lb.
46's Carding	...	...	34 $\frac{1}{2}$ lb.	56's Carding	...	...	180 lb.
44's Preparing	...	...	20 $\frac{1}{2}$ lb.	50's Carding	...	...	16 lb.
44's Carding	...	...	$\frac{1}{2}$ lb.				246 lb.
40's Preparing	...	...	6 $\frac{1}{2}$ lb.	Average weight of fleece	...	...	7 $\frac{1}{2}$ lb.
36's Preparing	...	...	2 lb.	Lightest	...	...	5 $\frac{1}{2}$ lb.
			205 $\frac{1}{2}$ lb.	Heaviest	...	...	10 lb.
Average weight of fleece	...	...	11 $\frac{1}{2}$ lb.				
Lightest	...	...	8 $\frac{1}{2}$ lb.				
Heaviest	...	...	13 lb.				

The following list expresses these results as percentages.

PERCENTAGE WEIGHTS OF NEW ZEALAND WOOLS OBTAINED BY SORTING FLEECES INTO THE VARIOUS QUALITIES

	Grev	36's Prepared	40's Carded	40's Prepared	44's Carded	44's Prepared	46's Carded	46's Prepared	48's Carded	48's Prepared	50's Carded	50's Prepared	56's Carded	58's Carded
	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Lot 386 Leicester 38's/42's	0.11	0.23	—	6.17	3.79	28.47	18.51	25.62	7.60	5.70	—	3.80	—	—
Lot 385 Romney ... 44's/46's	—	1.00	—	3.25	0.30	9.90	16.83	68.72	—	—	—	—	—	—
Lot 383 Romney ... 46's/48's	—	—	1.01	1.00	—	—	4.06	3.31	32.81	52.28	4.53	—	—	—
Lot 384 Corriedale 50's/56's	—	—	—	—	—	—	—	—	—	—	6.50	—	73.17	20.33

Most interesting deductions may be made from these results. These are as follows—

- (a) An attempt has evidently been made to "fine" the Leicester 38's/42's by cross breeding, with the result that this series of fleeces shows far too great a variation in the qualities present.
- (b) The 44's/46's Romney is evidently comprised of uniform fleeces and gives a reasonably uniform sorting result.
- (c) The 46's/48's Romney shows signs of having been "fined" by cross-breeding and is not quite so uniform in quality as the 44's/46's.
- (d) The 50's/56's Corriedale show evidence of careful selection. This would appear to indicate that by carefully selecting breeding stock, a breed of sheep tending to vary may ultimately be obtained at least normally uniform in quality.
- (e) The average weights of fleeces indicate one reason why the Romney is chief favourite. It would be interesting also to place carcase weights and complete financial returns alongside one another. That the average weight of the Corriedale fleeces is slightly above that of the Leicester fleeces is surprising; but again carcase weights and complete financial returns would be interesting.

From this medley of qualities, equal weights of the following were selected for experimental purposes.

44's Leicester	..	for Preparing	46's Romney	..	for Carding
46's Leicester	.	for Preparing	48's Romney	.	for Preparing
46's Leicester		for Carding	48's Romney	.	for Carding
46's Romney	..	for Preparing	56's Corriedale	..	for Carding

These were carried through the processes from scouring to cloth finishing as eight distinct lots under as nearly as possible identical conditions.

Microscopic Examination of Fibres—The fibres of all wools dealt with have been carefully examined for—

- (a) Average fibre diameter.
- (b) Variations in diameters (see Frequency Distribution Curves).
- (c) Contour of cross-sections.
- (d) Medullation.

The following list gives the complete analysis of representative fibres of the eight qualities of wool dealt with.

FIBRE DIAMETER ANALYSIS OF NEW ZEALAND WOOLS
(Note—These were made from the tops to ensure efficient sampling)

	English Leicester 44's Prepared	English Leicester 46's Prepared	Leicester 46's Carded	N Z Romney 46's Prepared	N Z Romney 46's Carded	N Z Romney 48's Prepared	N Z Romney 48's Carded	Corrie- dale 56's Carded
Mean Diameter ...	1/569"	1/554"	1/627"	1/587"	1/559"	1/604"	1/630"	1/642"
Maximum Diameter	1/375"	1/388"	1/375"	1/388"	1/388"	1/388"	1/437"	1/388"
Minimum Diameter	1/875"	1/807"	1/1050"	1/875"	1/807"	1/954"	1/807"	1/954"
Mean Deviation ...	2.54	2.59	3.00	2.27	2.90	3.04	2.08	2.27
% Mean Deviation ...	13.77	13.67	17.93	12.70	15.43	17.50	12.4	13.90
Standard Deviation	3.18	3.07	3.85	2.97	3.58	3.63	2.58	2.89
% Standard Deviation	17.2	16.2	23.0	16.6	19.0	20.9	15.5	17.7

Plate I—Fibre Diameters

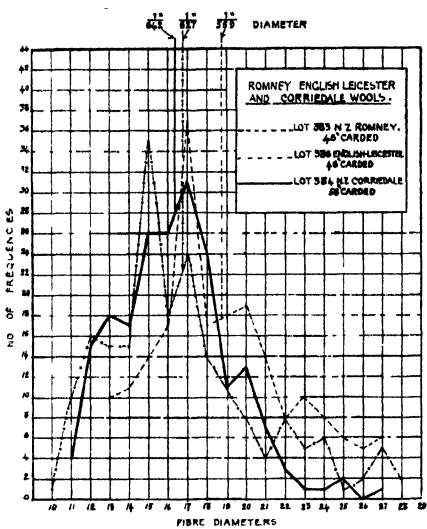


Fig. 1

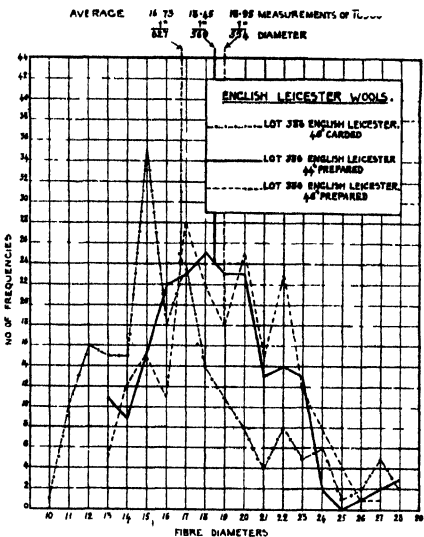


Fig. 2

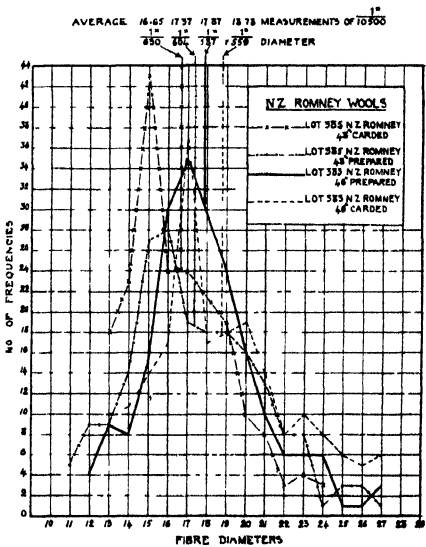


Fig. 3

Frequency Distribution Curves

From these particulars the following deductions may be made.

- (a) There is not a great difference between average diameters of these wools, the extremes being—

46's Leicester (Preparing) ... 1/554" and
56's Corriedale (Carding) ... 1/642"

- (b) The highest percentage standard deviation is the 46's Leicester—carding (23%). This is accounted for by the fine fibres (1/1050 in.) present.
(c) The lowest percentage standard deviation is the 48's Romney—carding (15.5%). This is accounted for by the absence of thick fibres and also of fine fibres, this quality obviously being the least variable of all the qualities in fibre diameter. This also accounts for its average diameter approaching that of the Corriedale which has been sorted as a 56's quality.

The three Diameter Frequency Curves (Plate I) may usefully be studied.

To check these results other qualities of these four wools were dealt with.

Six compound qualities of these wools were manufactured on similar lines as follows—

A blend of Leicester	..	..	40's, 46's, 48's, and 50's qualities
A blend of Leicester	...	..	44's, 46's, and 48's qualities
A blend of 44's/46's Romney	..	..	36's and 44's qualities
A blend of 46's/48's Romney	..	..	46's and 48's
A blend of Corriedale	..	..	50's and 58's
Pure Corriedale	...	..	58's

The Diameter Frequency Curves fully confirmed these already given.

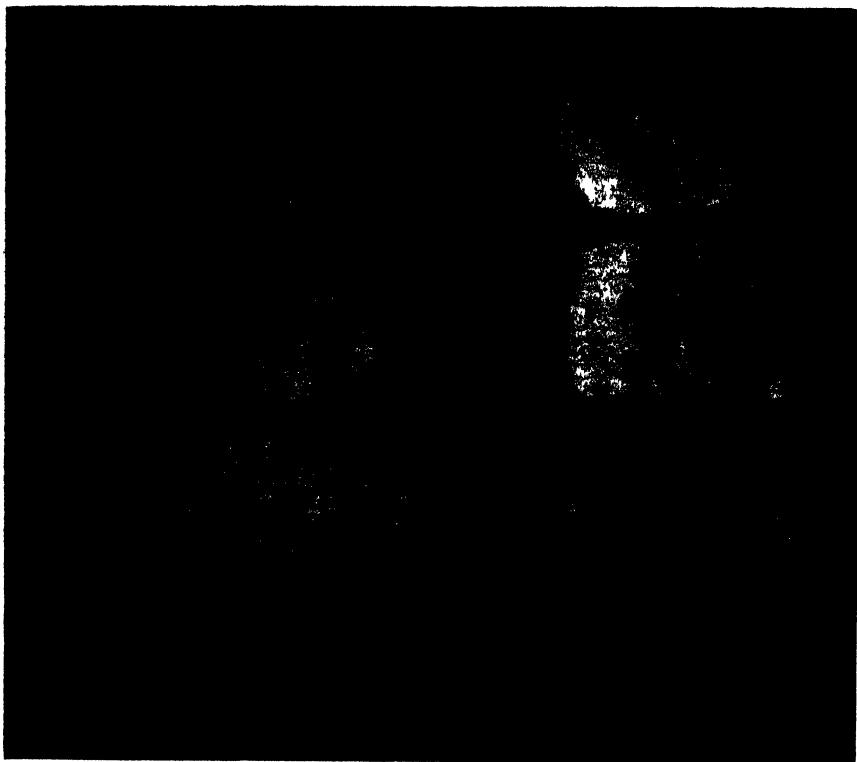
The following list is extraordinarily interesting in that it includes examination with polarised light and spinning efficiency. These two run together and it is suggested that colouration under polarised light indicates an orientation of crystalline or micelle structure which accompanies brittleness of "fibre-stuff" and that naturally the more brittle a fibre is the lower will be its spinning qualities. It is also thinkable that if the contours of cross-sections of Romney fibres are curious that this may be accounted for by the different orientation or crystallisation, if such be there. Colouration or lack of colouration, however, may simply be due to differences in fibre-diameter. Thus thick fibres may be simply opaque, medium fibres coloured, and fine fibres again simply opaque. These matters are being fully investigated by Mr. W. T. Astbury, in the University of Leeds, and before long much more will be known about these phenomena.

FIBRE ANALYSIS OF NEW ZEALAND WOOLS

(Note—These were made from the Tops to ensure efficient sampling)

	English Leicester 40's, 46's, 48's, 50's	Leicester 44's, 46's, 48's	Romney 36's, 44's	Romney 46's, 48's	Corriedale 50's, 58's	Corriedale 58's
Variation in Diameter	1/337" to 1/1166"	1/375" to 1/1166"	1/388" to 1/1050"	1/375" to 1/954"	1/388" to 1/1166"	1/437" to 1/1050"
Mean Diameter	1/572"	1/582"	1/563"	1/578"	1/617"	1/689"
% Mean Deviation	15.85	17.24	16.96	15.92	16.17	15.70
% Standard Deviation	19.6	21.2	19.5	21.0	19.8	19.7
Polarised Light	6 Very coloured	5	4 Fairly	3 coloured	2 Very little coloured	1
Actual Order of Spinning Efficiency	6	5	4	3	2	1

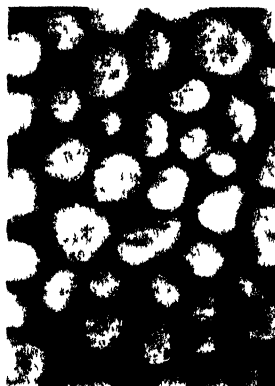
Plate II



Romney Wools—illustrating "tippiness."



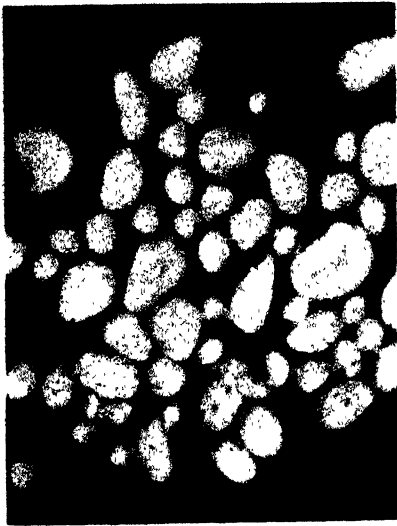
Leicester—44's Prepared.



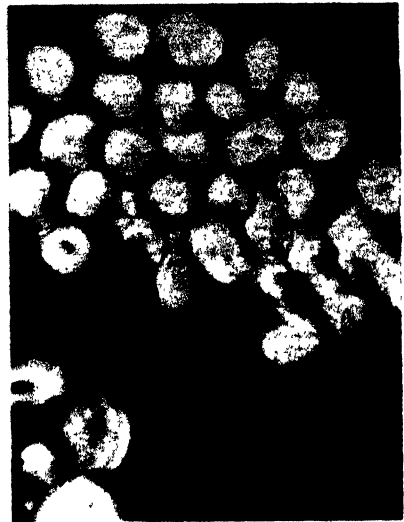
Corriedale—56's Carded.

Photo-micrographs.

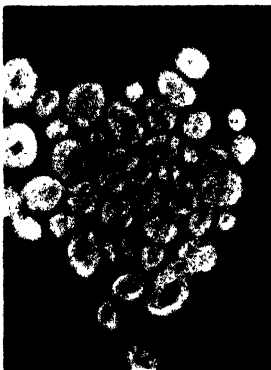
Plate III—Photo-micrographs—New Zealand Romney Wools



40's Carded.



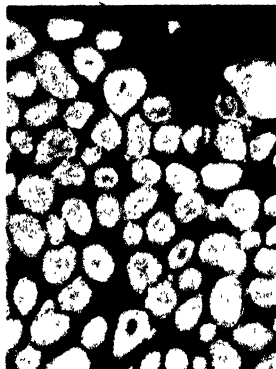
40's Prepared.



46's Carded.



46's Prepared.



48's Carded.

The accompanying photo-micrographs (Plates II and III) are illuminative with reference to "contours of cross-sections." The 40's Romney, carded, shows Romney wool at its worst. The two photo-micrographs on a larger scale (450 magnification in place of 270) give the right idea of quality number based on fibre diameter, but also give a more important suggestion, viz., that the kidney-shaped cross-section may appear in Corriedale as well as in Romney wools. This would further lead to the suggestion that the difference in spinning quality between these two wools resides not in cross section difference but in "fibre-stuff," as already suggested. Thus, differences in cross-sections may be indicative of the cause of the difference in spin without being the actual cause in themselves.

With reference to "medullation": although a few fibres are shown medullated in the Romney, these may also be regarded as "indicative" rather than the cause of the difference in "spin."

Yields—On scouring under similar conditions, the following results were obtained—

44's Leicester (prepared)	.. 75%	46's Romney (carded)	.. 61%
46's Leicester (prepared)	. 75%	48's Romney (prepared)	. 78%
46's Leicester (carded)	.. 70%	48's Romney (carded)	. 67%
46's Romney (prepared)	. 83%	56's Corriedale (carded)	.. 63%

These results were obtained from the top, noil, and waste, as the carded types were carded wet and could not be weighed as they came from the wash bowl.

The Combing (top) Results—The wools having been "prepared" or "carded" and "combed" under similar conditions were "finished" and the resultant "tops" were submitted to the Bradford Conditioning House for "fibre length analysis" on the Schlumberger Top Analysing Machine. The following are the results—

SCHLUMBERGER TOP ANALYSES FOR LENGTH

Percentage Weights of each length

Cms.	Leicester 44's Prepared	Leicester 46's Prepared	Leicester 46's Carded	Romney 46's Prepared	Romney 46's Carded	Romney 48's Prepared	Romney 48's Carded	Corriedale 56's Carded
29	0.21	—	—	—	—	0.28	—	—
28	0.25	—	—	—	—	0.66	—	—
27	0.63	0.46	—	—	—	1.09	—	—
26	0.94	0.70	—	0.34	—	2.73	0.33	—
25	1.77	0.76	0.31	0.72	—	3.45	0.39	—
24	2.92	1.61	0.35	1.68	0.17	4.29	0.58	—
23	3.55	2.81	0.76	3.44	0.37	4.74	1.03	—
22	5.05	3.50	1.46	3.93	0.64	4.99	1.21	—
21	5.36	5.06	2.33	6.58	1.43	4.45	2.13	—
20	5.93	5.57	2.44	7.07	2.52	4.57	2.77	—
19	5.39	5.87	4.40	7.37	2.89	4.37	3.00	—
18	5.47	5.36	4.71	7.37	3.32	3.80	3.72	0.31
17	5.35	4.66	4.93	6.75	4.03	3.87	4.10	0.43
16	4.85	4.93	4.84	5.80	5.16	4.27	4.42	1.38
15	5.22	5.09	5.19	5.52	5.91	4.43	4.42	3.20
14	6.18	5.84	5.19	5.75	6.91	4.29	5.35	5.32
13	6.14	6.76	5.59	4.91	7.29	4.17	5.83	8.35
12	5.57	5.69	6.12	4.42	7.86	4.00	6.14	10.88
11	4.38	5.27	5.94	4.20	7.86	3.97	6.14	11.83
10	3.76	4.20	6.03	3.65	6.68	3.36	5.91	11.23
9	3.30	3.20	5.94	3.12	6.01	3.84	6.75	10.45
8	3.23	3.32	5.65	3.03	5.33	4.18	6.28	9.11
7	3.59	3.70	5.72	2.58	5.06	4.06	6.36	7.62
6	3.01	4.60	6.00	2.71	5.18	3.93	5.74	6.23
5	2.46	3.86	5.25	2.65	5.07	3.36	5.21	4.03
4	1.89	2.68	4.36	2.16	4.34	3.42	4.52	3.30
3	1.56	1.93	3.28	1.55	3.15	2.43	3.64	2.81
2	0.90	1.07	1.76	1.28	1.42	1.48	2.21	1.93
1	1.14	1.50	1.45	1.42	1.41	1.42	1.82	1.59

Plate IV—Top Analyses—Milling Results

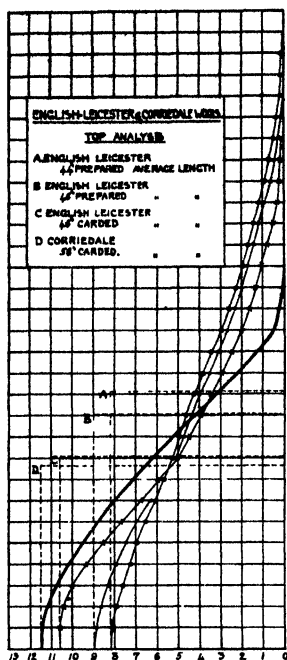


FIG. 1

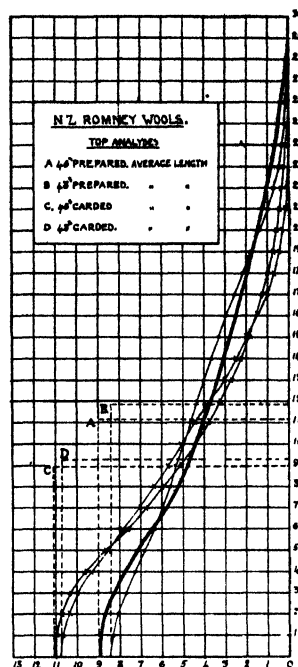


FIG. 2

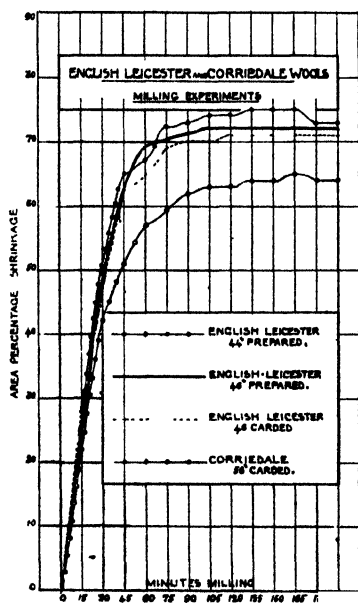


FIG. 3

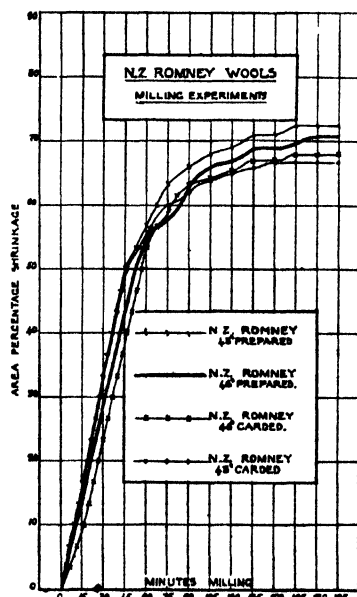


FIG. 4

These figures have been worked out in graph form (Plate IV) on a strictly comparative basis* and give just the results which, with one interesting exception, might be anticipated with reference to length analysis. One factor of possible variation—that of length—between these wools has therefore been eliminated so far as the following experiments are concerned.

The suggestion previously raised—that of fibre breakage owing to the diameter/length ratio—must not be passed over. This will be partly revealed by the “tearage” in combing. These are as follows—

44's Leicester (prepared)	...	10 to 1
46's Leicester (prepared)	...	9.9 to 1
46's Leicester (carded)	...	9.7 to 1
46's Romney (prepared)	...	11 to 1
46's Romney (carded)	...	10 to 1
48's Romney (prepared)	...	8.5 to 1
48's Romney (carded)	...	7.2 to 1
56's Corriedale (carded)	...	8.7 to 1

It will be noticed that the two 48's Romney give the most noil of any in the series, thus suggesting fibre weakness and breakage. The following comparisons are useful for deciding this point.

	Average		Length	Ratio
	Diameter			
44's Leicester (prepared) ...	1/569"	...	12.0 cm.	1.19 × 10 ⁵
46's Leicester (prepared) ...	1/554"	...	11.0 cm.	1.16 × 10 ⁵
46's Leicester (carded) ...	1/627"	...	9.4 cm.	1.19 × 10 ⁵
46's Romney (prepared) ...	1/587"	...	11.9 cm.	1.20 × 10 ⁵
46's Romney (carded) ...	1/559"	...	9.3 cm.	1.14 × 10 ⁵
48's Romney (prepared) ...	1/604"	...	11.0 cm.	1.20 × 10 ⁵
48's Romney (carded) ...	1/630"	...	8.9 cm.	1.17 × 10 ⁵
56's Corriedale (carded) ...	1/642"	...	8.7 cm.	1.18 × 10 ⁵

From these figures it will be realised that four of these tops are 11 cm. or over in average length and that the 48's Romney (prepared) has a fibre diameter of 1/604 in. as against 46's Leicester (prepared) 1/554 in. This does suggest more possible breakage of the 48's Romney and this has actually occurred during the preparing and carding, the 48's Romney (prepared) only tearing 8.5 to 1 against the 46's Leicester (prepared) 9.9 to 1. These conditions are reversed, however, between the 46's Romney (prepared) and the 46's Leicester (prepared). In the Carded tops the 48's Romney and the 46's Leicester have approximate diameters, the Romney is shorter than the Leicester and yet only gives 7.2 to 1 tearage as against 9.7 to 1, thus again supporting the idea of fibre weakness. In the case of the 46's Romney (carded) and the 46's Leicester (carded) the Romney diameter is coarse, they are about the same length and the Romney tears 10 to 1 as against 9.7 to 1 so that in this case the fibre strengths appear to be about the same.

From these particulars it is suggested that the 48's Romney wool is distinctly weaker in fibre than either the 46's Romney or the 46's Leicester; but the 46's Romney and Leicester are fairly comparable.

The broad tearage result, however, suggests that the Leicester qualities have broken more in Preparing and Carding than the 46's Romney but much less than the 48's Romney.

It is further interesting to note that the 48's Romney (carded) is similar in diameter and length to the 56's Corriedale, but tears only 7.2 to 1 as against 8.7 to 1. But the 48's Romney (prepared) is coarser in diameter.

* See Peruvian Report for method of graphing.

longer in fibre but has only given a tearage of 8.5 to 1 as against the Corriedale 8.7 to 1.

The diameter : length ratios give the two Romneys (prepared) as the greatest in the series, thus again supporting the idea that the Romney wools are "overgrown."

These figures show that the two Romney prepared tops are relatively to diameter the longest in the series, being closely followed by the 44's Leicester prepared.

THE SPINNING (YARN) RESULTS

The only yarn spinning unfavourably commented on by the spinner was the 46's Romney (carded) In the following list the Single-thread Strength and Elongation results are given. A further attempt is made to arrive at "Spinning Efficiency" by obtaining as nearly as possible a cross-sectional fibre-break by bringing the jaws of the testing machine as close to one another as possible, thus obtaining what may conveniently be regarded as a "fibre-break" and putting the 18-in. breaks into percentage terms of this "fibre-break." This gives the 46's prepared Romney and Leicester as markedly the best spinning tops and the 46's Carded Romney as the worst spinning top. The finer fibre of the 48's Romney (carded) probably explains the superior spinning efficiency of this top to the 48's Romney (prepared)

SINGLE-THREAD STRENGTH AND ELONGATION TESTS OF 1/4½'s WORSTED COUNTS

	Tested with Jaws 18" apart		Tested with Jaws close together	
	Strength oz	Elongation in	Strength oz	Elongation in
44's Leicester (prepared)	41 05	3 74	70 95	24
46's Leicester (prepared)	50 77	4 64	75 85	25
46's Leicester (carded)	43 32	2.92	75 82	20
46's Romney (prepared)	47.97	4 64	65 32	24
46's Romney (carded)	40 32	3 83	74.37	25
48's Romney (prepared)	42 92	3 41	70 72	20
48's Romney (carded)	43 15	3.75	70.50	24
56's Corriedale (carded)	45 80	2 95	75 02	20

SPINNING EFFICIENCY 1/4½'s WORSTED

	Spinning Efficiency
44's Leicester (prepared)	57 8%
46's Leicester (prepared)	66 9%
46's Leicester (carded) ...	57 3%
46's Romney (prepared)	73 4%
46's Romney (carded)	54 2%
48's Romney (prepared)	60 6%
48's Romney (carded)	61 2%
56's Corriedale (carded)	61.1%

Sometimes the frequency distributions of such a series of tests serve to show up points of difference. The following lists give the frequency for the foregoing. There appears to be only one anomaly in this—the 65.32 oz. Jaw Test for 46's Romney (prepared). There may be an experimental error here which gives the 46's Romney (prepared) rather too high a "spinning efficiency."

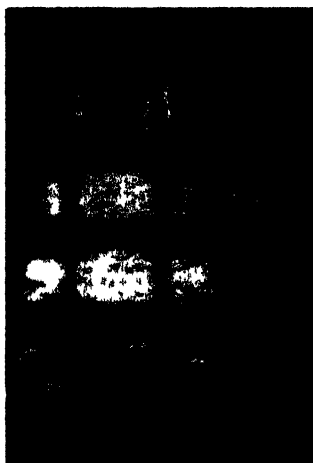
Plate V—Combing Results



N Z Romney—46's Prepared



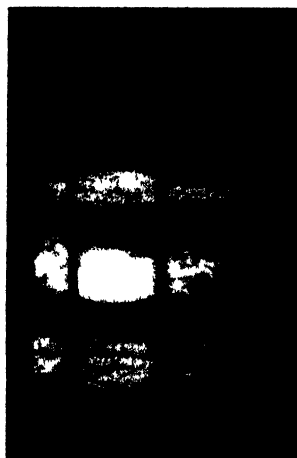
N Z Romney—48's Prepared



English Leicester—46's Prepared



N Z Romney 46's Carded



N Z Romney—48's Carded



English Leicester—46's Carded

STRENGTH FREQUENCIES OF 1/41's WORSTED COUNTS

Strength in oz. 18 in. Tests	386 Leicester 44's Prepared	386 Leicester 46's Prepared	386 Leicester 46's Carded	383 Romney 46's Prepared	383 Romney 46's Carded	385 Romney 48's Prepared	385 Romney 48's Carded	384 Corriedale 58's Carded
18 in. Tests Averages	41.05	50.77	43.32	47.97	40.32	42.93	43.15	45.8
Oz								
54—57.9	—	6	—	2	—	—	1	1
50—53.9	—	8	1	6	—	1	1	3
46—49.9	4	3	4	7	—	4	4	5
42—45.9	6	3	9	2	9	6	7	7
38—41.9	3	—	6	3	5	6	5	4
34—37.9	6	—	—	—	4	3	1	—
30—33.9	1	—	—	—	2	—	1	—
Total Tests ...	20	20	20	20	20	20	20	20
Jaw Test Averages	70.95	75.85	75.82	65.32	74.37	70.72	70.50	75.02
Oz								
92—95.9	—	2	—	—	—	—	—	—
88—91.9	1	1	1	—	—	—	—	—
84—87.9	1	—	1	—	—	1	1	1
80—83.9	2	3	4	1	3	3	2	5
76—79.9	1	1	4	1	6	1	2	3
72—75.9	4	5	5	1	3	1	5	6
68—71.9	3	6	3	4	6	6	1	2
64—67.9	4	1	1	7	1	5	6	2
60—63.9	3	1	—	2	1	1	1	1
56—59.9	—	—	1	—	—	1	1	—
52—55.9	1	—	—	4	—	1	1	—
Total Tests ...	20	20	20	20	20	20	20	20

Innumerable further tests have been made with other sortings of the four lots of wools. These broadly confirm the results given above and further serve to show the difficulties involved in such tests. The following list, for example, is illuminative.

Spinning Efficiency Tests for 1/20's Worsted Counts (8 turns per inch)

Leicester (40's, 46's, 48's, 50's) ...	22%
Romney (36's and 44's) from 44/46's Bale	33%
Leicester (44's, 46's, 48's) ...	35.5%
Corriedale (50's and 58's)...	36%
Romney (44's and 48's) from 46/48's Bale	37.5%
Corriedale (58's) ...	42.5%

These are in the order which would be anticipated with the exception of the Corriedale (50's and 58's). But relatively to quality number the suggestion is frequently given that Corriedales are elastic rather than plastic wools and that the fibres do not "bed" into the thread as the more plastic wools do.

THE WEAVING RESULTS

The weaving comments fail to show any discrimination except with reference to the 46's Romney (prepared) which obviously wove very well, and the 46's carded rather adversely commented on. All the "prepared" yarns wove better than the corresponding "carded" yarns. As it is useful to compare tests of "cloth out of the loom" with the variously "finished cloths," the strengths, etc., results of the greasy cloths are given in the succeeding section.

THE FINISHED FABRICS—STRENGTH AND ELONGATION

The strength and elongation tests are given in the three following tables. These require the expert to read, but the following deductions may safely be made.

- 1—In the warp strength tests for “milled finish” all the yarns gain in strength over the “cloth from loom,” with the exception of the 56's Corriedale (carded) and the 46's Romney (carded).
- 2—In the weft strength tests all the yarns lose in strength except the 46's Romney (prepared), while the 48's and 46's Romney (carded) lose remarkably at the “scoured finish state.” The 56's Corriedale (carded) does not relatively lose as much as the other “carded” yarns.
The disintegrating action of the scouring and milling action on weft yarns is here admirably illustrated.
- 3—By averaging warp and weft strength tests and thus arriving at reasonable comparative results the order of “strength tests” is as follows—

	Based on “Milled Finish”
46's Romney (prepared) ...	131.00 lb.
56's Corriedale (carded) ...	125.98 lb.
48's Romney (carded) ...	121.58 lb.
46's Romney (carded) ...	121.31 lb.
46's Romney (prepared) ...	119.78 lb.
46's Leicester (carded) ...	109.83 lb.
46's Leicester (prepared) ...	105.24 lb.
44's Leicester (prepared) ...	99.88 lb.

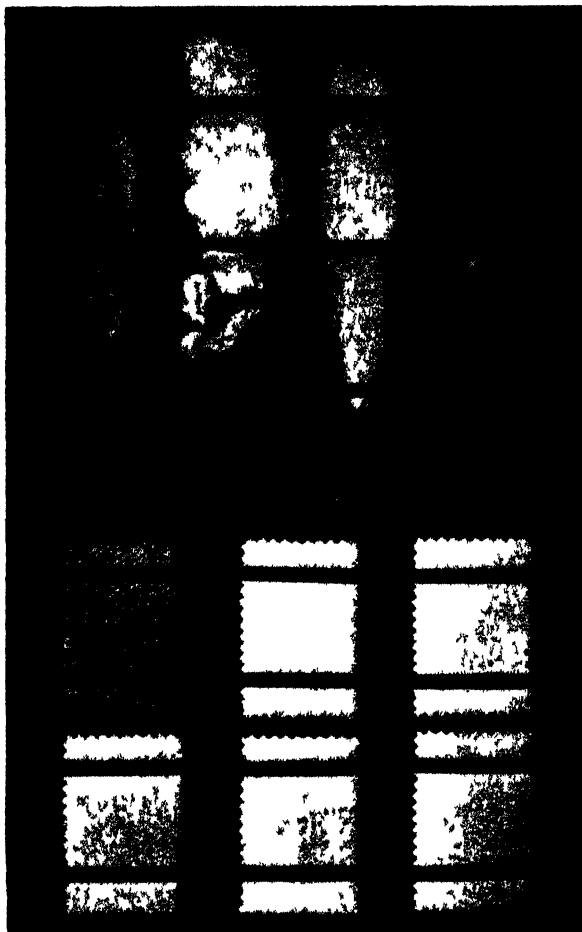
It will be noted that with the exception of the 46's Romney (prepared) the “carded” yarns always test stronger than the corresponding “prepared” yarns, no doubt owing to the better milling properties of “carded” as against “prepared” yarns.

- 4—Comparing these results with the “yarn strength” tests (18 in.) it will be noticed—
 - (a) That the 46's Romney (prepared) has taken the place of the 46's Leicester (prepared) at the head of the list and has maintained its position before the Corriedale.
 - (b) That the Corriedale yarn then retains its position; followed by the three Romneys which in cloth strength are markedly superior to the Leicesters, principally owing to the well recognised good finishing properties of Romney wools.

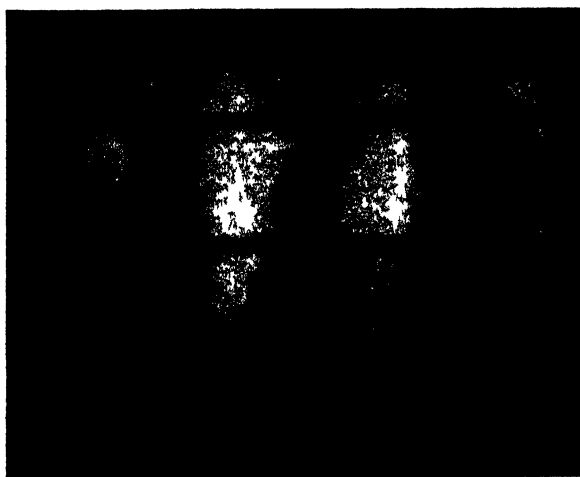
I—WARP STRENGTH TESTS

	Leicester 44's Prepared	Leicester 46's Prepared	Leicester 46's Carded	Romney 46's Prepared	Romney 46's Carded	Romney 48's Prepared	Romney 48's Carded	Corrie- dale 56's Carded
Cloth from Loom ...	lb. 121.22	lb. 106.67	lb. 118.20	lb. 131.35	lb. 121.66	lb. 112.38	lb. 119.92	lb. 149.8
Scoured ...	116.07	109.9	116.72	120.74	116.5	108.64	117.63	134.8
Scoured Finish ...	108.70	102.22	113.83	122.02	117.73	105.77	118.40	130.38
Half-milled Finish ...	123.52	127.66	113.07	130.79	124.40	114.41	120.62	124.77
Milled Finish ...	123.44	120.33	127.37	135.29	121.40	122.40	130.67	126.65

Plate VI



English Leicester—44 s Prepared



Corriedale—56's Carded.

WARP ELONGATION TESTS

Cloth from Loom ...	in. 2·606	in. 2·37	in. 2·26	in. 2·50	in. 2·25	in. 2·17	in. 2·15	in. 2·25
Scoured ...	2·45	2·41	2·37	2·78	2·51	2·28	2·26	2·36
Scoured Finish ...	2·19	2·08	2·22	2·62	2·37	2·08	2·16	2·53
Half-milled Finish ...	2·22	2·44	2·17	2·48	2·24	2·20	2·07	2·45
Milled Finish ...	2·44	2·48	2·40	2·48	2·44	2·44	2·49	2·79

II—WEFT STRENGTH TESTS

	Leicester 44's Prepared	Leicester 46's Prepared	Leicester 46's Carded	Romney 46's Prepared	Romney 46's Carded	Romney 48's Prepared	Romney 48's Carded	Corrie- dale 56's Prepared
	lb	lb	lb	lb	lb	lb	lb	lb
Cloth from Loom ...	134·44	142·81	129·57	117·25	145·9	140·86	137·07	147·12
Scoured ...	129·47	141·66	130·66	131·79	136·12	136·125	132·45	142·17
Scoured Finish ...	113·83	125·21	113·83	122·92	52·92	108·10	67·02	115·15
Half-milled Finish ...	58·55	80·96	82·22	90·00	86·87	91·15	86·50	124·01
Milled Finish ...	76·32	90·15	92·30	126·72	121·22	117·17	112·49	125·31

WEFT ELONGATION TESTS

Cloth from Loom	in. 2·637	in. 2·708	in. 2·42	in. 2·39	in. 2·44	in. 2·35	in. 2·35	in. 2·77
Scoured ...	2·66	2·56	2·57	2·82	2·59	2·49	2·48	2·93
Scoured Finish	2·26	2·22	2·25	2·56	1·60	2·22	1·51	2·54
Half-milled Finish	2·62	2·79	2·89	2·30	2·16	2·25	2·25	3·12
Milled Finish	3·34	3·50	3·37	3·18	2·01	2·99	2·96	3·46

III—AVERAGE OF WARP AND WEFT STRENGTH TESTS

The same number of threads tested in each case.

	Leicester 44's Prepared	Leicester 46's Prepared	Leicester 46's Carded	Romney 46's Prepared	Romney 46's Carded	Romney 48's Prepared	Romney 48's Carded	Corrie- dale 56's Carded
	lb.	lb.	lb.	lb	lb.	lb.	lb.	lb.
Cloth from Loom ...	127·83	124·74	123·88	124·30	133·78	126·62	128·49	148·46
Scoured ...	122·77	125·78	123·69	126·26	126·31	122·38	125·04	138·48
Scoured Finish ...	111·26	113·71	113·83	122·47	85·32	106·93	92·71	122·76
Half-milled Finish ...	91·03	104·31	97·64	110·39	105·63	102·78	103·56	103·49
Milled Finish ...	99·88	105·24	109·83	131·00	121·31	119·78	121·58	125·98

AVERAGE OF WARP AND WEFT ELONGATION TESTS

Cloth from Loom ...	in. 2-61	in. 2-53	in. 2-34	in 2-44	in. 2-34	in 2-26	in. 2-25	in 2-51
Scoured ...	2-55	2-48	2-47	2-80	2-55	2-38	2-37	2-64
Scoured Finish ...	2-20	2-15	2-23	2-42	1-98	2-15	1-83	2-53
Half-milled Finish ...	2-42	2-61	2-53	2-32	2-20	2-22	2-16	2-78
Milled Finish ...	2-89	2-99	2-88	2-44	2-72	2-71	2-72	3-12

- 5—Upon the whole, it would seem that the excellence of these Romney wools in finishing well compensates for disadvantages in spinning, such as those noted with reference to 46's Romney (carded), for example.
- 6—The "elongation" tests are chiefly noticeable for the position of the "Corriedale" which seems to suggest that the Corriedale will be the fullest cloth and the 46's Romney (prepared) the leanest cloth. This suggestion is confirmed by the handle of the cloths.
- 7—The Corriedale is much the whitest of all the cloths, this quality no doubt coming from its merino ancestry. A research upon the relative wool-colours of Merino, Down, and Lustre breeds of sheep is suggested. The two Romneys would seem to come next although not nearly so white as the Corriedale.

THE FINISHED FABRICS—SHRINKAGE

In the accompanying graphs (Fig. 3, Milling Graphs) the effects of milling or felting after scouring are clearly shown. The contraction in area in all the Leicester qualities approaches its limit at 75 minutes, and at 195 minutes the 44's quality is showing indications of expansion, i.e., of disintegration. The Corriedale is somewhat later in coming to its maximum shrinkage, but it also shows evidences of expansion at 180 to 195 minutes. The Romney qualities in their final results approach the Leicester qualities, but the curves are similar to the Corriedale. There is considerable creasing of the curves until at 150 to 165 minutes the final positions are reached.

The most characteristic features of these curves are—

- 1—The position of the Corriedale which, not being due to "carding" is probably in part due to its shortness (see Graph, Plate VI); but, as the 48's Romney (carded) is only slightly longer and yet shows more shrinkage, may be attributed to "fibre-stuff" or "scale structure." The "fibre-stuff" is most likely to be the cause of the difference as the scale structure of Corriedale should slightly favour contraction in comparison with the Romney.
- 2—The "carded" qualities always shrink less than the "prepared" qualities, thus further confirming the Leeds University investigation into British wools.*
- 3—Although there is little difference in shrinkage, the 48's Romney (prepared) shrink slightly more than the 46's Romney (prepared). The 48's Romney (carded), however, shrinks the least of the series, thus suggesting its affinity with the Corriedale.

Reference will be made to these results in further milling tests.

**Journal of Textile Science*, 1924 and 1925.

I. SPECIAL TESTS FOR ROMNEY WOOL

The complaint of Sir Frederic Aykroyd, as representative of Bradford spinners, has claimed special consideration.

Two Romney yarns were submitted by Sir Frederic, viz.—

Yarn from a 40's Prepared Top.

Yarn from a 46's Carded Top.

In both cases coarse fibres were picked off the surface of the yarns and when measured were found to be only about $1/276$ in.

After these fibres had been picked off the yarn, the remaining fibres were measured under the microscope and compared with corresponding fibres, as indicated in the following list.

ROMNEY MARSH WOOLS—DIAMETER MEASUREMENTS

	From 44's/46's Romney		From 46's/48's Romney		From Yarns of Sir F. Aykroyd	
	36's Prepared	44's Prepared	40's Carded	50's Carded	40's Prepared	46's Carded
Maximum Diameter ...	1/362"	1/420"	1/362"	1/437"	1/362"	1/362"
Minimum Diameter ...	1/1166"	1/1500"	1/1500"	1/1166"	1/954"	1/1166"
Average Diameter ...	1/542"	1/605"	1/612"	1/668"	1/533"	1/574"
Mean Deviation ...	3.1625	2.3225	3.2868	2.3912	3.3655	3.0814
% Mean Deviation ...	16.3	13.38	19.1	15.2	17.09	16.86
Standard Deviation ...	3.94	3.10	4.042	2.95	4.09	3.89
% Standard Deviation	20	17.8	23	18.7	20.7	21.3

From these results it will be noted that—

- (a) No further strong fibres were discovered.
- (b) The fine fibres ($1/1500$ in.) appear in two of the samples, curiously enough in the ones showing the greatest and least % Standard Deviations.

(NOTE—It is not yet known what the value from the spinning point of view, if any, the % Standard Deviation possesses, but researches are in progress to settle this point)

- (c) The remarkable correspondences between the Romney, Leicester, and Corriedale wools are worthy of note, suggesting that there should be little difference in spinning and manufacturing so far as diameter analyses are concerned.

A further examination was then made of the mixed quality blends previously referred to, but no different results from those recorded were obtained. Special microscopic examinations of the surface of the "finished cloths" have also been made to discover abnormally thick fibres but none such have been discovered in the qualities here reported upon.

It would thus appear that the thick fibres in Sir Frederic Aykroyd's yarns were "accidental," but whether they had actually come (grown) in the fleeces, or been left in through inefficient sorting, or through the lack of thorough cleaning of the machinery through which they had passed, cannot be decided here. It seems probable, however, that one or other of the two first causes cited, or both, are the most likely cause of the defect. Such strong fibres would undoubtedly cause a defective "spin."

II. A FURTHER INVESTIGATION INTO THE OBSERVED SPECIAL "SHRINKING PROPERTIES" OF ROMNEY WOOLS IN FINISHING HAS ALSO BEEN MADE

The Textile Technologist usually considers the contraction of a cloth from the loom to the finished state to be due to the following factors.

1—Contractions due to a balancing up of interlacing strains in the fabric.

NOTE—The balancing up of shrinkage in length and in width requires careful consideration

2—Contractions due to a reversion to the natural "fibre curvatures" incident upon wetting in the scouring process.

3—True "milling" or "felting" due to the influence of one or more of the following factors.

(a) Scale structure.

(b) Fibre length—either directly or indirectly

(c) Fibre stuff lending itself to more or less elongation during the spinning processes; this along with the two previously given factors, being brought more and more into play when assisted by the heat developed in milling.

4—Type of milling machine employed, the "stocks" tending to "crush" or "burst" as against the "milling machine" tending to compress the fabric.

The particulars already given of finishing contractions are very interesting in the light of the above factors, and the following particulars give additional interest to the investigation.

The following experiments arose from the suggestion that certain long-fibred wools might be more susceptible to elongation during spinning than others, and that, if so, these wools would be—

(a) Least elongated in the Woollen Carding and Mule Spinning process,

(b) More elongated in the Worsted Carding, Combing, Drawing, and Spinning process; and

(c) Most elongated in the Worsted Preparing, Combing, and Drawing and Spinning processes.

If such elongation took place it would be unlikely to attain to a 70% extension and, therefore, on wetting, the fibres (and the cloths into which these fibres were made) might be expected to contract. Thus contraction would come under (3b) indirectly, and (3c) of the above factors.

To test this, the same qualities of 46's and 48's Romney wools were dealt with as follows—

(a) The short fibres (noil) was spun into woollen yarns and woven under standard conditions.

(b) The prepared "top" (see Plate IV, Fig. 2) was spun into worsted yarns and woven under standard conditions.

(c) The prepared "top" (see Plate IV, Fig. 2) was cut into 4-in. lengths, carded and spun into worsted yarns and woven under normal conditions.

The following list gives the results of finishing these six cloths and, in conjunction with those already given, may help to elucidate the difficult subject of "milling."

**46's and 48's NEW ZEALAND ROMNEY WOOLS
SPECIAL MILLING EXPERIMENTS**

Type of Wool	In Loom		Cloth from Loom			Scoured Cloth			After Milling for 60 minutes		
	Width	Length	Width	Length	Shrinkage	Width	Length	Shrinkage	Width	Length	Shrinkage
46's Woollen (nolls) ...	36"	—	33½"	36"	0%	31½"	35½"	9%	19"	25½"	60%
48's Woollen (nolls) ...	36"	—	34½"	36"	0%	31"	35½"	11%	18½"	25½"	62%
46's Prepared Worsted ...	36"	—	34"	36"	0%	31"	35"	12%	18½"	25½"	62%
48's Prepared Worsted ...	36"	—	34½"	36"	0%	31½"	35"	11.5%	17½"	25½"	65%
46's Prepared Worsted (cut)	36"	—	34½"	36"	0%	31½"	35"	10%	17"	25½"	66%
48's Prepared Worsted (cut)	36"	—	35½"	36"	0%	32½"	35½"	11%	16½"	24½"	69%

From these particulars and Plate IV, Figs. 3 and 4, the following deductions may be made.

- 1—So far as the main natural shrinkage which occurs in "scouring" is concerned, the idea of "long fibre extension" and subsequent contraction is supported, for the orders of shrinkage are—

	Woollen		Cut Worsted		Prepared Worsted
46's Quality	9%	...	10%	...	12%
48's Quality	11%	...	11%	...	11.5%

- 2—The idea of "long fibre extension" is not supported by the milling results for these give—

	Woollen		Prepared Worsted		Cut Worsted
46's Quality	60%	...	62%	...	66%
48's Quality	62%	...	65%	...	69%

- 3—The cloths, however, at 60 minutes milling are obviously in a state of transition and these results in conjunction with Plate IV, Figs. 3 and 4 do suggest that fibre contraction is a factor—if only small—in milling. Probably fibre wave, thread structure and actual fibre contraction do combine to produce in yarns what is spoken of as "creep" prior to weaving.
- 4—If milling is largely a question of fibre length (as Plate IV, Figs. 3 and 4 suggests) then in the above list at 60 minutes milling "prepared worsted" and "cut worsted" should not reverse places.
- 5—That the "cut worsted" does give the most contraction, even at 60 minutes milling, suggests that there is a latent effect in the fibres which is emphasised in the "cutting" of the fibres and this can only be the extensions to which they have been subjected at first combing and in the subsequent (after cutting of the top) carding, drawing and spinning.

Thus the argument runs—

Prepared worsteds give greater contractions than carded worsteds.

Carded worsteds give greater contractions than carded woollens.

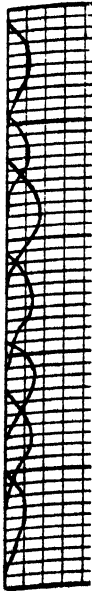
Long-fibred cloths give, relatively, more scouring shrinkage than short fibred cloths.

Short-fibred cloths give, relatively, more milling contraction than long fibred cloths.

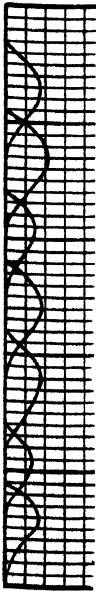
If the suggestion, given later in the treatise, that worsted yarns are broadly of the "shell" fibre structure and woollen yarns of the "variable fibre-angle" structure, then, in the "cut fibre" worsted cloths the advantage in contraction of the "shell" type of yarn will be gained, with the possible addition of "creep" and fibre contraction.

Plate VII—Yarn Untwisting and Retwisting Graphs.

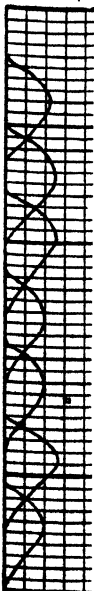
Carded Yarns.



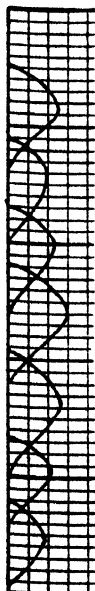
46's N.Z. Romney.



48's N.Z. Romney.

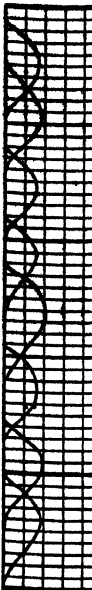


46's English Leicester.

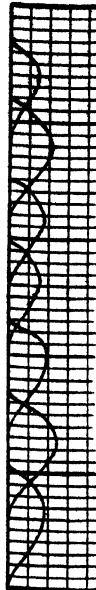


56's Cornedale.

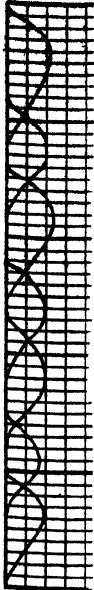
Prepared Yarns.



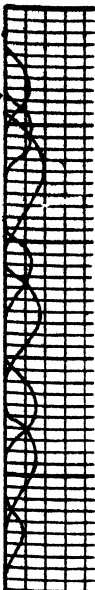
46's N.Z. Romney.



48's N.Z. Romney.



46's English Leicester.



44's English Leicester.

The reason why short fibred cloths contract more in milling may be chiefly due to fibre "creep," such creep being held by the scale structure of the fibres; and to fibre contraction in a lesser degree. That either fibre contraction or the nature of the fibre-stuff must be taken into account is clearly suggested by the Corriedale result. The cutting of the fibres in the foregoing experiments may be viewed as releasing the latent strains in the longer fibres rather than simply giving a shorter fibred yarn.

Dr. J. B. Speakman, of the University of Leeds, is making a most thorough investigation of the factors of milling and his report is anticipated with much interest.

III. THE FIBRE STUFF—YARN EXPERIMENTS

The yarns from which the foregoing cloths have been made have been "graphed" by means of Barker's Twist Tester (Plate VII).

From these graphs the following list has been compiled—

Yarn	Twist per in.	% Extension
44's Leicester (prepared) ...	4.90 ...	1.45
46's Leicester (prepared) ...	5.39 ...	2.06
46's Leicester (carded) ...	4.92 ...	1.86
46's Romney (prepared) ...	4.65 ...	1.75
46's Romney (carded) ...	5.07 ...	1.28
48's Romney (prepared) ...	4.97 ...	2.29
48's Romney (carded) ...	4.96 ...	1.68
56's Corriedale (carded) ...	4.85 ...	2.33

These graphs yield the following interesting results—

1—"Prepared" yarns always give more extension than "carded." This distinctly suggests that carded yarns tend to take a "variable fibre-angle" structure (though not to the same degree that woollen yarns do), and the prepared yarns the "shell" or "similar fibre-angle" structure.

2—Arranging the "carded" and "prepared" series in order of increasing extension, the following is the order—

Carded	Prepared
46's Romney ...	44's Leicester
48's Romney ...	46's Romney
46's Leicester ...	46's Leicester
56's Corriedale ...	48's Romney

The 46's Romney (carded) is the least extensible and most "wiry" yarn, this confirming the spinning report.

The 44's Leicester (prepared) comes next.

The 56's Corriedale (carded) is the most extensible yarn followed by the 48's Romney (prepared), while the 46's Romney is definitely less extensible than the 46's Leicester, and even the 48's Romney (carded) is less extensible than the 46's Leicester (carded).

This suggests the more "wiry" or "rigid" nature of the Romney wool as compared with Leicester wool and a much more wiry nature than the Corriedale. If the Corriedale wool had been prepared, the difference between it and the 48's Romney would obviously have been greater.

3—The two most regular curves are the 44's Leicester (prepared) and the 46's Romney (prepared and carded). The most irregular curves are the Corriedale (carded) and 48's Romney (prepared). The quicker fall (retwisting) in the two latter curves is usually more marked and suggests a "setting" not so noticeable in the more "wiry" yarns.

- 4—The turns per inch may express what is termed “creep” in yarns. It will be noticed that the two lowest qualities (44's Leicester—prepared, and 46's Romney—prepared) show the least creep as judged by twist, with the exception of Corriedale. Probably a correction of % extension as influenced by twist should be made. 46's Romney (prepared) and 46's Leicester (prepared) show the greatest difference in twist. This, if allowed for, will bring their % extension very close together. These twists and extensions were checked by the additional following tests, which confirmed the figures given.

		Twist per in		% Extension
46's Leicester (prepared) ...	...	5.57	...	2.14
46's Romney (prepared) ...	...	4.81	...	1.79

NOTE—On looking at Plate VII the suggestion comes up strongly that the Romney Wools, Carded and Prepared, have been accidentally crossed. In an experiment lasting over two years, even with the greatest care, this may happen. An endeavour is being made to repeat this experiment as its confirmation, or otherwise, may prove very important.

GENERAL CONCLUSIONS

1—In the wools submitted, nothing has been revealed which places the Romney wools in an inferior class to the other wools. The Romney wools take their natural place between the Lustre and Down types with the possible exception of 46's Romney (carded).

2—The Romney wools show signs of being of a “cross-bred” type, since

- (a) Very fine fibres frequently occur, possibly leading to a too high-quality number being given to these wools; and
- (b) Wiry fibres of the distinct Lustre breed type seem to form the bulk of the lower Romney qualities;
- (c) Romney fibres seem to tend towards the length of the Lustre wools and the fineness of the Down breeds, the ratio of fibre length to fibre area being higher and tending towards fibre-breakage in carding, preparing, and combing. This tendency towards length may also explain the “tippy” nature of certain Romney fleeces

3—Further support is given to the idea of Romney wools being of a “cross-bred” type by the sorting results which suggest—

- (a) That very great care should be exercised in selecting stock for breeding purposes, and to obtain the most uniform fleece possible.
- (b) That very great care should be taken in the sorting of these wools.

4—It is suggested that the wiry nature of Lustre wools may be due to the crystalline structure or the orientation of the crystalline structure as judged by examination under polarised light; but the “spring” or elasticity or nature of Down and Corriedale wools is due to some other factor. Romney wools may possess one or both of these “natures” and thus has possibly the greatest “lift” of all wools. This naturally decreases its spinning quality.

5—It follows from (4) that great care should be exercised in crossing the Romney with any other breed as a combination of bad points in some fleeces is quite likely to appear in the resultant cross.

6—The “finishing” results suggest that the Romney “fibre-stuff” is of a more extensible nature than Down “fibre-stuff,” giving a much better milling result. This cannot be attributed to the scale structure as Romney, Southdown, and Corriedale give approximately the same “scale-friction” results (Speakman's experiments).

7—Well-bred Romney wools possess qualities of great value for certain types of yarns and fabrics, but should not be indiscriminately employed.

NOTE—Many of the methods of testing employed in this report are only just being developed in the University of Leeds, and their import has not yet been fully appreciated nor always understood. Some of the results are surprising: where possible these have been checked by repetition. It is hoped that further useful deductions may be made from these results by intensive study and that such deductions may be checked by further experiments.

My thanks are due to Mr. Hollis and Mr. Yewdall for the spinning, weaving, and finishing of these yarns and fabrics; to Dr. Chamberlain for the cutting and photo-micrography of the sections of Romney, etc. wools; to Mr. Farley for assistance in preparing the diagrams; and especially to Mr. Pickles and his assistants; also to Mr. C. L. Novotny for the care exercised in the many tests carried out, only about one-third of which appear in the report, and to the practical staff of the department.

APPENDIX

Since this report was written other opportunities have arisen for further examining the supposed defects of New Zealand Romney wools. In the examples given, what is known as "tippiness" is well illustrated. These particular wools have been examined under polarised light, with the following results.

- 1—The "tippy fibres" are strongly coloured all along their lengths from tip to root, but are possibly slightly less coloured at the roots.
- 2—The bulk fibres are only a little coloured or not coloured at all.
- 3—The "tippy fibres" are thicker than the bulk fibres, as shown in the following list.

Staple I			Average Dia.		Minimum Dia.		Maximum Dia.
Tippy Fibres (middle)	...	...	1/508"	...	1/1050"	...	1/350"
Bulk Fibres (middle)	...	...	1/636"	...	1/1170"	...	1/420"
Staple II							
Tip Measurement (50 Fibres)	...	...	1/491"	...	1/700"	...	1/390"
Root Measurement (50 Fibres)	...	...	1/614"	...	1/700"	...	1/460"

At the root of the 50-fibre staples, 25 other fibres were found. These being taken into account gave the following result—

Root Measurement (75 Fibres)	...	1/665"	...	1/1050"	...	1/460"
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It is thus quite evident that while the "tippy" are thicker than the bulk fibres, they themselves tend to thin down at their roots. *It would further appear that the colouration may be partly dependent upon biological growth and not on fibre diameter only*, although as pointed out on page 166, this is still open to question.

Cross-bred wools, which show marked colouration under polarised light, tend to what is termed "break" in finishing if creased: the fibres are obviously brittle and not plastic. By inference, these "tippy fibres" will be brittle, and may reasonably be expected to interfere with the spinning not so much from their greater diameter as from the "nature" of the fibre-stuff of which they are composed.

There has just come to hand from Dr. Dry, who is at present working in New Zealand, some interesting particulars about the "birth-slump" in fibre-growth, and a reference to "persistent fibres." It looks as though these "persistent fibres" are the "tippy fibres" of the later growth. But why the fibre-stuff should be different and how it is different is the question: and the solution probably lies in the combined work of Dr. Dry and Mr. W. T. Astbury.

A. F. B.

8—SOME CASES OF MILDEW ON SILK-CELLULOSE ACETATE MATERIALS

By F. V. DAVIS, B.Sc.

(British Silk Research Association)

The work of several investigators, notably Thaysen and Bunker (Biochem. J. 19) and Hayes and Holden (J.T.I. xxiii, T. 93) has shown that cellulose acetate is extremely resistant to micro-organisms, by which it is virtually unattacked. These investigations appear to base their conclusions on mechanical tests and on the microscopical examination of yarns or fibres composed solely of cellulose acetate. The results of an inquiry into the cause of the defective dyeing of the cellulose acetate in several samples, illustrative of many, of silk-acetate silk crepe cloths which have been submitted to the British Silk Research Association by Mr. F. Kendall of the Bradford Dyers' Association during the last twelve months indicate, however, that the dyeing properties of cellulose acetate may be altered by the growth of "mildew" on materials with which it is in contact. As circumstances prevent the investigation being carried further at present, the results already obtained are now communicated as they appear to be of considerable interest and importance.

The defect consists in the occurrence of patches of lighter shade in dyed crepe cloth, composed of a cellulose acetate warp (gelatin sized) and a real silk weft; the real silk is of course woven in the undegummed state and the cloth is boiled off before dyeing. Four lengths of this material which have been stored in the grey before degumming and dyeing were submitted; of these, two lengths were dyed blue, one green, and one black. All four lengths showed numerous light patches which, singly, were almost circular in outline, but which in numbers formed irregular lines following the silk weft.

Dissection of the fabrics showed that the marks were invariably on the cellulose acetate warp, and that the shade of the silk weft was unaffected. This suggested that although the defect was apparent in the cellulose acetate warp, its cause was to be sought in the silk weft, and it was suspected that mildew growth originating on the silk had affected the dyeing properties of the cellulose acetate.

A preliminary microscopical examination of all the lengths of fabric submitted, showed that in the spots of lighter shade the surface of the cellulose acetate was pitted, and spores of some kind were entangled in the filaments. This observation was confirmed by several observers. Neither spores nor pitting were observed in the unaffected portions of the fabrics.

MYCOLOGICAL PROCEDURE

Three of the fabrics were examined mycologically; the marks on the black fabric were not sufficiently distinct to enable them to be cut out with certainty. Cultures were prepared from light patches cut out from each cloth, and also from unaffected parts of each fabric, by soaking 0.1 gram. in twenty cubic centimetres of sterile water at 25° C. for half an hour, and plating out 0.2 c.c. of each liquor on to separate plates of culture medium. For the first lengths of fabric submitted, (No. 1 in table below), the medium used was nutrient agar incubated at 40° C. and examined after 48 hours; for each of the other two lengths examined two media were used; wort agar

incubated at 40° C. and examined after 64 hours, and nutrient gelatin incubated at 25° C. and examined after 64 hours. The counts of micro-organisms per gram of material, estimated from the plates are given in the Table below. Each result is a mean of two determinations, and "blank" plates were incubated with each series.

MICRO-ORGANISMS PER GRAM OF MATERIAL

	CLOTH NUMBER					
	1		2		3	
	Lab. Sample No. 1682		Lab. Sample No. 1857		Lab. Sample No. 2061	
Bacterial colonies ...	Marked 135,000	Normal 12,000	Marked 40,000	Normal 7,600	Marked 0*	Normal 10,000
Fungal colonies ...	—	—	6,250	1,875	6,000	0

*Plate covered with fungal growth

The following types were isolated from the cultures—

(a) Bacteria

- (1) Motile bacillus, wrinkled greyish-white colonies on agar. White spreading colonies on potato. Infundibuliform liquefaction of gelatin. No indol-formation or denitrification. *B. subtilis*.
- (2) Motile oval bacillus, showing polar staining. Greyish-white colonies on agar. Infundibuliform liquefaction of gelatin. Wrinkled growth on potato. No denitrification or indol-formation. *B. mesentericus*.
- (3) Motile bacillus, with subterminal spores. Shiny white colonies on agar. Stratiform liquefaction of gelatin. Moist brownish growth on potato. No denitrification or indol-formation.
- (4) Motile bacillus, often with two spores to a cell. Shiny light cream colonies on agar. Infundibuliform liquefaction of gelatin. Moist greyish growth on potato. No denitrification or indol-formation.
- (5) Non-motile coccus in short chains. Yellow colonies on agar, turning orange. Gelatin liquefied, with yellow growth. Thin white expansion on potato, which later becomes moist and orange. *Staphylococcus aureus*.

(b) Mould-fungi

- (1) *Penicillium*, globular conidia, about 2 μ diameter, on pointed cylindrical sterigmata. Dark green growth on wort agar, gradually turning brownish.
- (2) *Penicillium*. Globular conidia, about 4 μ diameter, on cylindrical sterigmata. Pale green growth on wort agar, slowly turning darker.
- (3) *Penicillium*. Globular conidia, about 6 μ diameter sometimes growing direct on mycelium. Conidiophores small, irregularly branched and with few sterigmata. Brownish growth on wort agar. *Penicillium brevicaulis*.
- (4) *Aspergillus*. Globular warty conidia on radial sterigmata attached to a pale stem and spherical globule. Brown-black luxuriant growth, with conidiophores several millimetres high, on wort agar. *Aspergillus niger*.
- (5) *Mucor*. Not examined.

Nos 1, 2, and 3 were preponderant, Nos. 4 and 5 only occurred to a limited extent.

Thus the number of micro-organisms present in the defective portions of the fabrics examined is considerably greater than the number in the unaffected portions, though the counts given are only relative. Although the resistant powers of spores are well known, it is extremely interesting to find spores in an active state after the degumming process and dyeing which the fabrics have undergone. It is regarded as extremely unlikely that these spores will have been introduced subsequent to dyeing, as the interval between dyeing and examination was short, and the irregular distribution noted above points to their presence before dyeing.

One or two attempts to grow colonies in situ, by soaking portions of the fabrics in culture media, both solid and liquid, and then incubating, failed to give definite results, though local liquefaction of the gelatin was observed in one or two cases.

Attempts to reproduce the defect

Numerous attempts have been made to reproduce the defect, as outlined below, with varying success.

(1) Pieces of cellulose acetate knitted material were spotted with dilute suspensions of a *B. mesentericus* culture on agar, and a *Penicillium* culture on gelatin obtained from the defective part of one of the fabrics. The pieces were stored in Petri dishes in a closed desiccator, containing water, for fourteen days at room temperature (18°–20° C.) They were then washed in a 0.2% soap solution at 60° C., and dyed with Duranol Green B at 65° C., for half an hour. The piece spotted with *B. mesentericus* showed no irregularities after dyeing, but the piece spotted with *Penicillium* showed a light patch where the mould had been growing, surrounded by a dark ring.

(2) A more elaborate series of experiments was carried out with cellulose acetate yarn, closely wound on glass plates with ground edges. Plates were wound with two brands of acetate yarn which had been (a) left untreated, (b) degreased in ammonia, (c) sized in $\frac{1}{2}\%$ gelatin solution at 70° C. for 10 minutes; six plates were wound, one with each sample. Cards rather smaller than the glasses were wound with a real silk crepe yarn known to be infected with *Aspergillus niger*, and one of these cards was fastened firmly to each glass plate with the crepe threads at right angles to the acetate. The pairs were then stored in a large desiccator over water, at 20°–25° C. for fifteen days. The glass plates were then removed, washed in $\frac{1}{2}\%$ soap solution at 60° C., and immersed in Duranol Green B at 65° C., for half an hour.

There were light markings following the crepe threads on the following plates—

Acetate silk, Brand A—Degreased with ammonia
Untreated
Sized

Acetate silk, Brand B—Degreased with ammonia
Untreated

With the exception of Brand A, sized, the markings were rather faint, however. It was considered that although the time of storage (a fortnight), was sufficient for the growth of the micro-organisms, it was doubtful whether any great chemical change in the acetate would be produced in that time

(3) Further experiments of a similar type were tried; but instead of binding cards wound with crepe silk yarn on to the glass plates of acetate yarn, the silk crepe yarn, degreased, sized and untreated, was stitched

through the acetate in the manner of a weft. These plates were stored in a desiccator as before, but were left for three months. They were then removed, washed, and dyed, as before. These plates all showed definite markings following the silk crepe yarn, and having an appearance similar to the marks on the faulty fabrics.

(4) Finally, an attempt was made to reproduce the defect on the large scale. Four cops of silk crepe yarns were allowed to mildew in a damp place, and were then woven across a sized cellulose acetate warp in a loom, with a band at each end woven with an un-mildewed silk crepe yarn. This piece was stored in a damp place for six months, after which, by the courtesy of Mr. F. Kendall, it was degummed, dyed, and finished technically. The piece presented the same appearance as the faulty lengths sent for examination; the end bands (composed of un-mildewed weft), were not so badly affected as the remainder of the piece. It is, of course, to be expected that these end-pieces would not be free from defects as micro-organisms would be present naturally on the silk weft used, and further, contamination by spores from the mildewed weft used would almost certainly occur during storage.

It is therefore, concluded that although the action of micro-organisms may have only a slight effect on a pure cellulose acetate yarn, it is probable that the micro-organisms present on a silk weft may, either themselves, or by means of their metabolic products, affect the dyeing properties, and hence the chemical composition of a cellulose acetate warp in contact with the silk. Probably the presence of gelatin size on the acetate warp, which provides nutriment for the micro-organisms favours this development. These results indicate that a dry place should be selected for the storage, which should not be prolonged, of a fabric of this description in the grey.

SUMMARY

(1) Patches of lighter shade on dyed fabrics composed of a real silk crepe weft and a cellulose acetate warp, have been shown to contain more micro-organisms per gram than the portions of normal shade.

(2) The silk is unaffected, but the cellulose acetate is affected as regards dyeing properties and appearance of the filaments.

(3) The defect has been reproduced on the small scale by storing silk yarn inoculated with micro-organisms in contact with cellulose acetate yarn, and then dyeing the acetate.

(4) The defect has been reproduced on the large scale by weaving a mildewed crepe weft across a cellulose acetate warp, storing in a damp place for six months and then dyeing.

(5) As a result of these experiments it seems certain that the growth of micro-organisms on a real silk crepe weft can result in an alteration of the dyeing properties of a cellulose acetate warp in contact with it.

The author expresses his thanks to Dr. W. S. Denham for helpful suggestions, and to Mr. F. Kendall of the Bradford Dyers' Association for his co-operation in this investigation.

9—THE STAPLING OF COTTONS

USE OF A STANDARD SHEET FOR RECORDING THE RESULTS FOR THE "COMBINED STAPLING TEST"

By A. W. BAYES, B.Sc.(Tech.), A.T.I.

INTRODUCTION

A method of measuring the main features of a sample of cotton has been described.¹ This method, called the "Combined Stapling Test," by analysis of the length of a sample of cotton, by weighing a standard length, and by estimation of the degree of thickening of the hairs, describes that sample. It has not yet been proved which measurement is the most important. They are all interdependent and their relative importance must depend on the particular use to which the cotton is to be put. In using this test, therefore, it is important that the measurements should be considered together. In routine testing mistakes of copying are eliminated and mistakes in calculation can be checked if the whole of the test results and calculations are confined to one sheet of paper.

For the Combined Stapling Test to be of maximum use to cotton growers and cotton spinners the results must be accurately comparable, and it is thought that some standard sheet would assist in the standardisation of the conditions and calculations of these tests. It is with this object in view that the sheet described in this paper has been designed.

DESCRIPTION OF THE STANDARD SHEET

General Layout of the Sheet

The calculations and constructions used in the standard sheet follow closely those used in the original paper.¹ The results are collected, together with the particulars of the sample tested, in the bottom right-hand corner, a position found by experience to be convenient. The test results and calculations radiate from this corner in approximately decreasing importance through the sorted hair weights and immaturities to the frequency diagram and finally the "details of sample" up at the top of the sheet.

Details of Sample

The first step in recording the results of a test is to state the particulars of the sample. The mark, type, origin, etc., being important, are put in the summary corner. The headings given cover most of the samples likely to be tested. In a test on a broker's sample, for instance, the broker's mark

MARK	C50	TEST NUMBER	101
		MIXING	X
TYPE	Texas I Low	GRADE	M
ORIGIN	Liverpool Cotton Assoc-	PRICE	30 on
	iation samples 1930	BASIS	5.00d

Details of sample. The mixing, grade, and price are put in for completeness, the actual values are fictitious.*

*The same cotton has been taken as an example throughout this paper. It is the example used by Miss Clegg, and is "N. America Texas 1, low," file number C50 of the Liverpool Cotton Association Samples, Table II of her paper.¹

would appear in the "mark" space; against "type" would appear "Texas" or "Sakel"; and against "origin" the name of the broker.

In recording such particulars it is useful to record also such details as grade, price as points on or off, and also the basis, as the points on are not necessarily a constant measure of the relative value of a cotton.

Where the tests are being done by a spinner a statement of the mixing or quality in which the mark is to be used is useful. The details of the sampling routine, unimportant in the individual test, but important in comparisons over long periods, or between samples from different processes, must be included in the sheet, but can be put in far from the centre of interest, i.e. the summary, under "details of sample." Under this heading would come, for instance for the broker's sample.

"32 tufts taken from various parts of a large broker's sample (20 bales) drawn, combined, and halved to give one tuft of 15 milligrams."

The sampling routine must vary between samples from the plant, the bale, or the yarn and even when comparing two similar samples, it is reassuring to see, without reference to other records, that the sampling routine is the same for both.

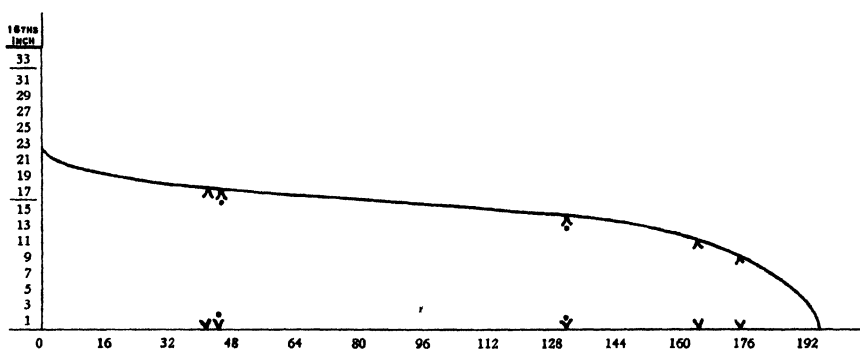


FIG. 1

Baer diagram of a Texas cotton (C 50) showing the major and minor quartiles (dotted arrowheads) and other points in the effective length construction

The Baer Diagram

The distribution of the hairs given by the Baer Sorter must be analysed to give the various length measurements; mean, mode, effective length, dispersion per cent., number of short hairs per cent.,* and the frequency distribution. Wherever these results are to be used in conjunction with English machinery the analysis should be made in fractions of an inch. The standard sheet is arranged to take paper ruled in 16ths of an inch. The shape of the Baer diagram is traced first on to a sheet of cellophane and then from this to a sheet of thin graph paper. This is cut along the base of the diagram and along the longest fibre, and is stuck on the upper space of the sheet so that the bottom of the longest fibre falls at the point marked O, the vertical scale marks off the fibre length in odd 16ths of an inch, and the horizontal scale

* The previous paper uses the expression "percentage of short hairs" throughout, but this is considered to be ambiguous, the measurement is actually the percentage of short hairs by number; as a percentage by weight the figure would be about half this value, and this should be borne in mind

marks off the length of the diagram in 32nds of an inch. It is convenient to have the diagram length measured in units of the order of one 32nd of an inch*.

Miss Clegg measures the diagram length in 16ths of an inch to the nearest half of a 16th, printing the figures in her example as 0.0, 0.5, 9.0, etc. These figures are not accurate to 0.1 of a 16th of an inch, because the curve of the diagram crosses the limits of classes lines at a small angle for much of its length, so that it is impracticable to determine, to such a degree of accuracy, the point at which the curve cuts a limit. 0.5 means to the nearest half of a 16th. In the standard sheet the scale along the base line has been multiplied by two to cut out the fraction and the ambiguous decimal point.

The method of splitting up the diagram follows Miss Clegg's scheme³ exactly but the full construction should always be completed. The extra time taken in finding the effective length over the time for the first approximation to the effective length is small compared with the trouble likely to be caused by two measures for the same effective length. There is no need to draw the complete construction on each graph, but it is worth while, for the purpose of checking, to mark each point with a small arrow-head and it is helpful to mark the arrow-heads indicating the effective length and the other measure used in finding the dispersion (the minor quartile) with a dot. The effective length is read off from the tracing in decimals of a 16th of an inch and written down in the 16ths inch column of the summary.

	16THS INCH	32NDS INCH	MILLIMETRES
MEAN HAIR LENGTH	14.61	29	23
MODAL HAIR LENGTH	16	32	25
MAJOR QUARTILE)	17.2	34	27
MINOR QUARTILE	14.0		
DIFFERENCE	3.2		
DISPERSION		19 %	
NUMBER OF SHORT HAIRS		10 %	

Summary of length figures and calculation of the dispersion % for a Texas cotton (C50).

Then the length to the nearest whole 32nd of an inch, and to the nearest whole mm., is put in the corresponding columns. The chief column of these three is that headed 32nds of an inch and the hair weight, dispersion, and number of short hairs figures should be kept in line with it. The dispersion calculation involves the estimation of two lengths, and the differences are so small that two observers may not agree on the final value of the dispersion for the same diagram. It is therefore important that these lengths, and the subtraction, should be shown on the test sheet. The construction, in effect, cuts off a standard number of hairs and then splits the remainder up into quarters,

*It would be more convenient if the units were marked off on the graph paper every ten, but this would necessitate the printing of special graph paper ruled in 16ths of an inch but divided again every five-16ths instead of every eight

the effective length is then the length of hairs at the end of the first quarter, and the dispersion per cent. is the difference between this length and the length of hairs at the beginning of the last quarter expressed as a percentage of the former. These lengths, in statistical language, are called the quartiles and to distinguish the two they have been called major quartile (effective length), and minor quartile, and the dispersion per cent. is therefore the inter-quartile range expressed as a percentage of the major quartile.

The quartiles are frequently named as "upper" and "lower" or as "first" and "third," the "second" quartile in this latter system being usually called the "median." Neither differentiation, being meant for the general case, conveys an impression of the relative values of the quartiles. The terms "major" and "minor" have been chosen, outside general practise, to define the quartiles more completely. The minor quartile, also, is read in decimals of a 16th of an inch, and the dispersion per cent. is calculated to the nearest whole number. The proportional number of short hairs is read off the tracing to the nearest 32nd of an inch, and is written down over the total of the "proportional number of hairs in each class" to give, directly, the fraction required for the calculation of the number of short hairs per cent. which is given to the nearest whole number.

The diagram has to be further analysed to find the frequency distribution and the mean and modal lengths. The frequency diagram gives a useful picture of the length of the cotton; the height and skewness giving immediately an impression of the regularity of the cotton. But for such a diagram to be an accurate guide, all specimens must be comparable.

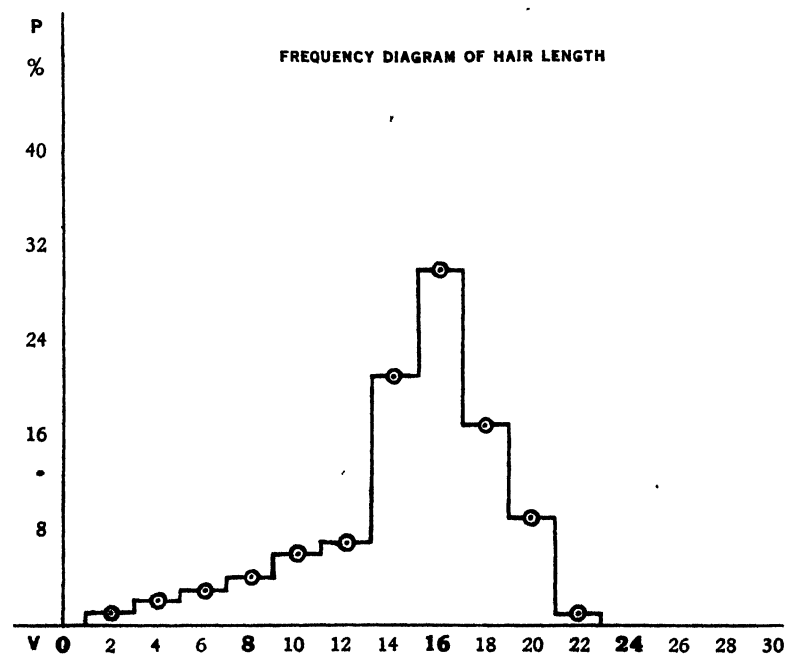


FIG. 2

Histogram of length of a Texas cotton (C50).

Successive Baer diagrams are likely to vary in length. Even an expert tester will get variations in diagram length from $3\frac{1}{2}$ inches to 8 inches, due to the type of cotton and to the hair density he happens to start with at the long hair end of the diagram. This variation increases the difficulty in directly comparing Baer diagrams, there being a tendency for the length of cotton in a short diagram to be underestimated when comparing it with an identical cotton in a long diagram. The Baer diagram can be reduced to a standard length, but a similar effect may be obtained more simply by plotting in a histogram, the length frequency as a percentage. This gives a frequency diagram of constant area, so that the heights of diagrams may be directly compared.

LIMITS OF CLASSES 16THS INS.	DISTANCE ALONG BASE LINE	V CLASS LENGTH 16TH INS.	F PROPORTIONAL NO. OF HAIRS IN EACH CLASS	P PER CENT. NO. OF HAIRS IN EACH CLASS	V x P
33		32			
31		30			
29		28			
27		26			
25		24			
23	0	22			
21	1	20	1	0.5	11
19	18	18	17	8.8	176
17	50	16	32	16.5	297
15	108	14	58	29.9	478
13	148	12	40	20.6	289
11	162	10	14	7.2	86
9	174	8	12	6.2	62
7	182	6	8	4.1	33
5	188	4	6	3.1	19
3	192	2	4	2.1	8
1	194	0	2	1.0	
		0	0	0	0
PROPORTIONAL NO OF SHORT HAIRS			19		
TOTAL			194	100.0	1461

Calculation of the frequency and mean hair length for a Texas cotton (C50).

The individual points should be plotted to the nearest unit and joined up as a histogram and not as a polygon, because the whole frequency calculation rests on the assumption of a series of classes of hairs of equal length and it is illogical and unnecessary to change the assumption for the production of a frequency diagram. The scale of the frequency diagram is

arranged so that the same graph paper can be used for it as for the Baer diagram. The calculation is done almost exactly as described in Miss Clegg's paper.

The limits of classes and the class length (the "variate," therefore lettered V) being constant, are printed in. P, the percentage number of hairs in each class, is calculated to the first decimal place, and then the relative weight of cotton in each class is calculated by multiplying $V \times P$. The variate could be multiplied by the frequency (F), but using P, the total has only to be divided by 100 to give the mean hair length in 16ths of an inch, and the distribution of hair length by relative weight is freed from the effect of the length of the Baer diagram

The precise value of this distribution is not evident. The calculation gives a frequency diagram whose area varies directly as the mean length. The figures could be reduced to a percentage, as has been done with the distribution by number, but it is suggested that this distribution is now in a sufficiently simplified form to be of use when a use for it is found. Perhaps the main disadvantage is that a constant hair weight has been assumed both along the diagram and along the individual hairs. Sufficient hairs are not weighed in one Combined Stapling Test to demonstrate a trend in hair weight along the diagram, but over a series of tests on one cotton a trend may easily be established and it has been shown that the hair weight per cm. tested as in the combined Stapling Test on centimetre lengths cut from the middle of the hairs is greater than the hair weight per cm. calculated from a knowledge of the weight and length of complete fibres.⁴ The same disadvantage is present in a frequency distribution by weight calculated directly from the proportional number of hairs in each class. But it is advisable to calculate the mean hair length, and it is suggested that if there is any value in the distribution by weight then it is presented in a useful manner in the "standard sheet."

Immaturity Count

The results obtained in the immaturity test are written down directly under the correct headings starting with long hairs. The percentage normal and dead is calculated for each count, then the five results are totalled and averaged, the mean value being written in the summary.

IMMATUREITY COUNT ON SORTED HAIRS					
	TOTAL NUMBER OF HAIRS	NORMAL HAIRS	DEAD HAIRS	% NORMAL	% DEAD
LONG	90	59	10	66	11
	97	70	10	72	10
	105	68	20	65	19
	80	60	10	75	13
SHORT	86	58	11	67	13
TOTAL				345	66

Example of an Immaturity Count on a Texas Cotton (C50).

Hair Weight per Centimetre

As in the Immaturity Count the results are written down directly and the hair weight calculated for each weighing. It is preferable to use the mean deflection to calculate the mean hair weight per centimetre, than to find the mean of the sorted hair weights.

HAIR WEIGHT PER CENTIMETER			CONSTANT OF BALANCE $118 \times 10^{-7} \text{ GM/CM}$	
	ZERO	DEFLECTED READING	DEFLECTION	$\frac{\text{DEFLECTION} \times \text{CONSTANT}}{100}$
LONG	3.7	22.8	19.1	225 $\times 10^{-8} \text{ GM/CM}$
	4.0	25.1	21.1	249 .. " "
	4.0	24.0	20.0	236 .. " "
	3.5	22.9	19.4	229 .. " "
SHORT	4.0	22.2	18.2	214 .. " "
TOTAL			97.8	
MEAN			19.6	231 .. " "

Example of a Hair Weight per Centimetre test on a Texas cotton (C 50)

The unit given on the standard test sheet is 10^{-8} gm. The unit of weight in the metric system is one gram and it is considered better to relate the unit of the hair weight test to this in one step as 10^{-8} gms than in two steps as 10^{-6} milligrams. The constant of the balance is liable to slight variation from month to month, and to considerable variation from balance to balance, and should be noted on each test sheet

It may be objected that such fine weighing as this is impracticable in a mill, but by fitting an air dash-pot to the balance described in Miss Clegg's paper and mounting the whole in a special case on sponge rubber, weighings can be done quickly throughout the day in mill office buildings and even inside the mill, on the ground floor. In cases of excessive vibration it is usually possible to arrange the work so that all weighings are done in the dinner hour while the mill is stopped.

Test Number

The test number is intended to cover the number used in the filing system. It is convenient in the case of routine tests to have the tests numbered consecutively.

The Standard Sheet as described, is intended to form the basis of the filing system for hair test results. It has been found convenient to file sheets for the current year loosely in boxes holding about 200 sheets each, and to put older sheets in box files, holding them in rings either by the side or by the top. The latter arrangement gives very easy access to the results when summarising tests over a period, or analysing trends in the sorted hair weights per cm. It has also been found useful in the mill to enter the summarised results on cards under such headings as "Brokers' Samples," "Marks Delivered," and "Mixings," and to put the mark and origin on an index card in single alphabetical order, for each test done.

HAIR WEIGHT PER CENTIMETRE			CONSTANT OF BALANCE		-7 / x 10 gm / cm	
ZERO	DEFLECTED READING	DEFLECTION	DEFLECTION		$\frac{\text{DEFLECTION} \times \text{CONSTANT}}{100}$	
LONG					x 10 gm / cm	
					"	
					"	
					"	
SHORT					"	
		TOTAL				
		MEAN			"	
REMARKS						
DATE OF TEST			SIGNED		TESTER	

182982

MARK	TEST NUMBER
MIXING	
GRADE	
PRICE	
BASIS	
MEAN IMMATURITY COUNT FIGURES NORMAL	
	% DEAD
	%
MEAN HAIR WEIGHT PER CENTIMETRE	x 10 gm
	MILLIMETRES
	16THS INCH
	32NDS INCH
MEAN HAIR LENGTH	
MODAL HAIR LENGTH	
EFFECTIVE HAIR LENGTH (MAJOR QUARTILE)	
MINOR QUARTILE	
DIFFERENCE	%
DISPERSION	%
NUMBER OF SHORT HAIRS	

APPENDIX

- 1—Graph paper for this sheet should be divided in 16ths of an inch and printed on "bank note" paper. A suitable paper is "Kinwest" by A. G. Thornton Ltd., Manchester.
- 2—A proportional compass is useful in dividing up the diagram into quarters for the effective length construction. "It cuts out the chance of error in counting out the quarters.
- 3—A slide-rule is useful for calculating all the percentages and products required.
- 4—Inquiries for the Standard Test Sheet should be sent to the Textile Institute.

REFERENCES

- ¹ Clegg, Gladys G. "The Stapling of Cottons. Laboratory Methods in use at the Shirley Institute, 1931"; *Journal of the Textile Institute* XXIII, No. 2, pp. 135-154.
- ² *Ibid.*, p. 144.
- ³ *Ibid.*, pp. 142-145.
- ⁴ Ahmad, Nazir. "Technological Reports on the Standard Indian Cottons, 1932; I.C.C.C., Techn. Bull. Ser. A, No. 12, p. 11.

2nd November, 1932.

Received 2/11/32

10—THE ESTIMATION OF WATER IN WOOL BY DISTILLATION

By C. O. M. STEWARD, A.R.C.S., A.I.C.

(Communicated by J. B. Speakman, University of Leeds).

Wool possesses a marked affinity for water, the amount adsorbed being determined by the temperature and relative humidity of the atmosphere, as well as by the thermal history of the wool and the direction (adsorption or desorption in which any particular humidity is approached. The amount of water in wool acquires exceptional significance from the fact that the behaviour of a material in carding, combing, spinning, and weaving, is determined to a remarkable degree by its water content. In any experimental study of these processes, as well as in routine trade practice, it is therefore extremely important to have some knowledge of the water content of the material being used. In addition, commercial transactions are carried out on the assumption that the product being bought or sold contains an amount of water fixed by the standards of regain. Since water is cheaper than wool, it is important for both buyer and seller to be certain that the commercial product contains the standard amount of water. The testing department of most firms is usually concerned only with this latter aspect of water adsorption, but the number of tests which can be carried out is limited by the size of the samples used in ordinary conditioning oven procedure, by the time taken to obtain the results and by the fact that conditioning ovens are expensive and each oven is capable of testing only three samples at a time. It is thus clear that even if the use of conditioning ovens is restricted to a firm's final product, only a limited control over its water content can be exercised. For this reason, it is usually impossible to free the conditioning ovens for the purpose of controlling the moisture content of a material at different stages of processing, and experimental studies of the influence of water content on the behaviour of a material in practice would be still more remote. For these and other reasons, the writer has been led to devise the following rapid method of estimating the amount of water in wool, a method which has proved eminently successful in routine testing.

EXPERIMENTAL

The principle of the method is essentially that proposed by Dean & Stark for estimating the amount of water in petroleum oil and emulsions by distillation with either xylol or a mixture of xylol and benzene. Their form of apparatus and experimental procedure were ultimately adopted by the Institute of Petroleum Technologists and are sufficiently well-known to require no detailed description. So far as the writer is aware, only two attempts have been made to adapt the Dean & Stark procedure to the estimation of water in wool and other textile materials^{1,2}. Without knowledge of this work, the writer made similar attempts to apply the distillation technique to the estimation of water in wool, but until recently certain drawbacks associated with the Dean & Stark method have precluded its use in routine textile testing. Among such defects may be noted the following—

- 1—Inflammable solvents are definitely undesirable.
- 2—There is a tendency for water to cling to the walls of the vertical condenser tube at the end of the distillation, thus minimising the accuracy of the estimation.
- 3—The distillate is warm and time must be allowed for it to cool to a standard temperature before readings of its volume may be taken.

These and other difficulties have now been overcome and the following method of experiment has been used successfully as a routine method of testing for several months. Thirty grams of a finished top, for example,

are taken from a finisher box and weighed rapidly on an automatic Avery Balance sensitive to .025 gram. After weighing, the top is transferred to a 2-litre brass conical flask and about 300 cc. of dry perchlorethylene, a solvent of high density (1.624) boiling at 119° C. are introduced. The flask is now closed by means of the special distillation tube shown in Fig. 1, the cork carrying the tube being painted with collodion flexible to obviate possible leaks. By means of a pipette, a little perchlorethylene is introduced through the hole in the side of the valve of the distillation tube in order to seal the side tube syphon. The flask is now transferred to an electric hotplate, the condenser is connected to the water supply and distillation carried out until all the water has been collected. The flow of vapour and liquid is continuous in direction and the water is carried along to the graduated tube, the whole of the apparatus being swept out by a current of vapour. Owing to the situation of the condenser, the condensed water is cold and its volume may be read off immediately. The rate of collection of water is shown by the curve of Fig. 2, and it is evident that the whole of the water is removed from the wool in 30 minutes from the time of commencement of heating. If the glass distillation tube is cleaned periodically with chromic acid, and with alcohol and ether after each estimation, separation of water takes place cleanly

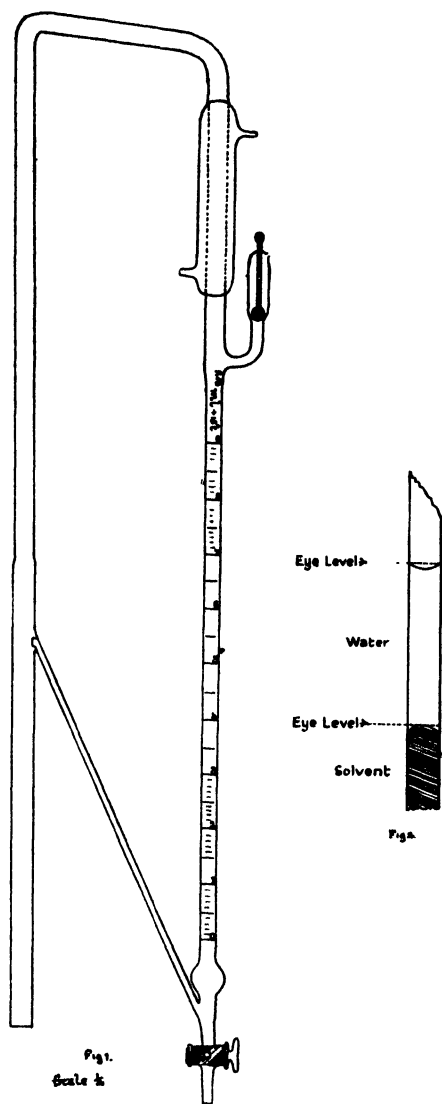


FIG. 1

and rapidly in the graduated tube. With a view to increased accuracy, the latter is graduated so that 1 cc. occupies a length of 3 cms. and it is possible to read the volume of water within 0.02 cc. in the manner shown in Fig. 1. During the distillation, all danger of charring the wool is obviated because the wool floats on the high density solvent and the boiling point of the latter is at 246° F., close to the temperature of 240° F. adopted by the Bradford Conditioning House for conditioning oven procedure.

After an estimation has been made, the perchlorethylene is transferred from the conical flask to an electrically heated still, for recovery. In practice, the still is run continuously to maintain a supply of clean solvent for the battery of eight flasks shown in Fig. 3.

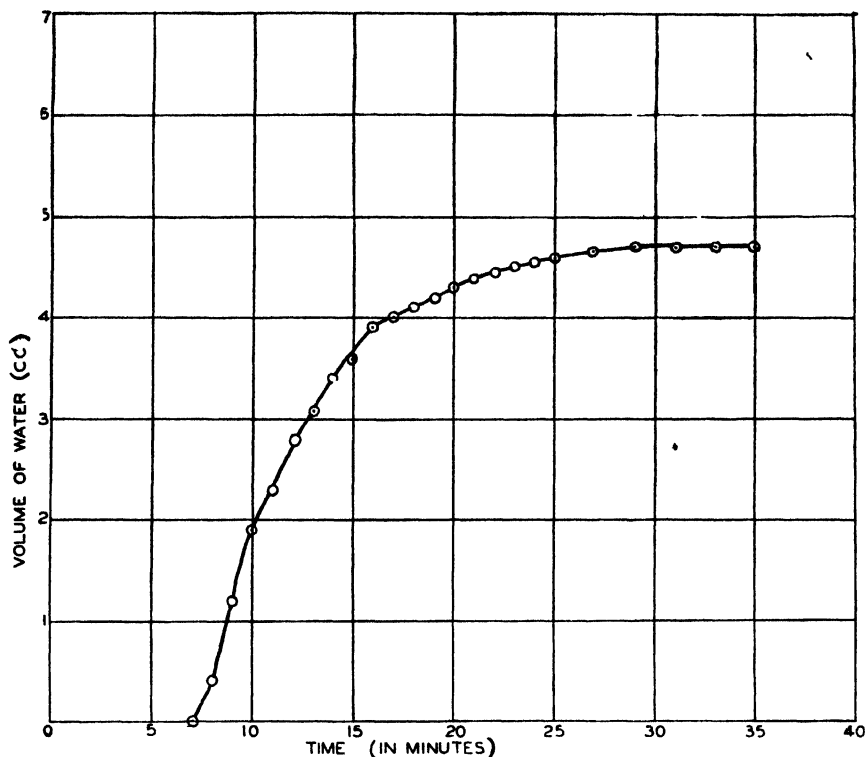


FIG. 2

RESULTS

With a view to testing the reliability of the new method of estimating the water content of wool by distillation, a series of parallel tests were carried out using the new method and the normal conditioning oven procedure with pairs of samples selected at the same time from the same top. The results are summarised in the table.

The deviation between pairs of results is nowhere serious and on the average of the whole series, the distillation procedure shows a slightly higher value for the water content of the various samples of wool. In view of the fact that the usual conditioning oven technique is known³ to leave 0.5% of water in wool, this difference between the two methods is probably real.

There can therefore be no doubt that the new method is equally reliable with the conditioning oven method for determining the amount of water in wool. It does, however, possess the following great advantages: with apparatus costing less than the conditioning oven, it is possible to determine the amount of water in wool more rapidly on smaller samples of wool, with the result that far more tests can be carried out by an unskilled observer in

Date	Description		Direct Loss %		Distillation 30 grams of wool sample of Wool)	Conditioning oven (½ lb. sample of Wool)	Difference
28/6/32	...	Room 1	Box 3	...	18.80	18.94	— .14%
	...	" 2	" 4	...	19.39	19.14	+ .25%
	...	" 2	" 10	...	16.08	16.40	— .32%
	...	" 3	" 5	...	16.25	16.02	+ .23%
	...	" 3	" 8	...	16.86	16.80	+ .06%
29/6/32	...	" 3	" 8	...	15.75	15.62	+ .13%
	...	" 3	" 5	...	15.92	16.01	— .09%
	...	" 2	" 4	...	14.10	14.06	+ .04%
30/6/32	...	" 1	" 8	...	14.92	14.84	+ .08%
	...	" 3	" 5	...	16.82	16.79	+ .03%
	...	" 3	" 3	...	17.25	17.19	+ .06%
1/7/32	...	" 4	" 13	...	17.85	17.58	+ .27%
	...	" 2	" 6	...	17.82	17.58	+ .24%
	...	" 2	" 9	...	15.82	15.62	+ .20%
	...	" 3	" 7	...	16.17	16.40	— .23%
	...	" 1	" 3	...	16.30	16.01	+ .29%
5/7/32	...	" 4	" 11	...	15.35	15.23	+ .12%
	...	" 4	" 10	...	15.77	15.62	+ .15%
	...	" 4	" 13	...	16.57	16.40	+ .17%
	...	" 3	" 8	...	16.82	16.79	+ .03%
	...	" 1	" 4	...	14.82	14.84	+ .02%
	...	" 1	" 5	...	14.92	14.84	+ .08%
6/7/32	...	" 3	" 5	...	15.25	15.23	+ .02%
	...	" 4	" 12	...	17.07	17.19	— .12%
	...	" 3	" 7	...	15.92	16.01	— .09%
	...	" 4	" 10	...	15.05	14.84	+ .21%
	...	" 4	" 13	...	15.05	15.23	— .18%
	...	" 3	" 3	...	16.05	16.01	+ .04%
	...	" 3	" 8	...	15.92	16.01	— .09%
30/6/32	...	" 3	" 6	...	15.77	16.01	— .24%
5/7/32	...	" 2	" 8	...	14.50	14.84	— .34%
6/7/32	...	" 1	" 3	...	15.30	15.62	— .32%
	...	" 3	" 6	...	15.00	15.23	— .23%
11/7/32	...	" 4	" 11	...	16.37	16.4	— .03%
	...	" 4	" 13	...	15.60	15.62	— .02%
12/7/32	...	" 3	" 11	...	16.60	16.41	+ .19%
	...	" 4	" 5	...	16.90	17.19	— .29%
12/7/32	...	" 4	" 8	...	16.47	16.80	— .33%
	...	" 4	" 9	...	16.07	16.01	+ .06%
	...	" 4	" 10	...	15.20	15.23	— .03%
	...	" 1	" 1	...	14.52	14.84	— .32%
	...	" 4	" 11	...	15.40	15.23	+ .17%
	...	" 1	" 10	...	16.22	16.01	+ .21%
	...	" 3	" 7	...	16.72	16.40	+ .32%
13/7/32	...	" 1	" 2	...	15.04	14.84	+ .20%
	...	" 1	" 5	...	16.22	16.40	— .18%
	...	" 3	" 5	...	16.12	16.01	+ .11%
14/7/32	...	" 2	" 6	...	16.22	16.01	+ .21%
	...	" 1	" 7	...	16.92	16.79	+ .13%
	...	" 4	" 13	...	16.07	16.40	— .33%
	...	" 4	" 11	...	16.05	16.40	— .35%
	...	" 2	" 8	...	16.00	16.01	— .01%
	...	" 1	" 8	...	16.00	16.01	— .01%
	...	" 4	" 19	...	16.32	16.40	— .08%
	...	" 4	" 13	...	17.45	17.58	+ .13%
	...	" 2	" 1	...	16.10	16.02	+ .08%
	...	" 4	" 12	...	17.26	17.19	+ .07%
	...	" 3	" 8	...	16.37	16.41	— .04%
	...	" 4	" 10	...	16.57	16.41	+ .16%
	...	" 4	" 11	...	16.85	16.80	+ .05%
15/7/32	...	" 4	" 11	...	16.85	16.80	+ .05%
	...	" 4	" 13	...	15.85	15.62	+ .23%
	...	" 4	" 12	...	16.10	16.02	+ .08%
	...	" 2	" 8	...	14.55	14.84	— .29%
	...	" 2	" 2	...	14.92	14.84	+ .08%
	...	" 4	" 12	...	16.90	16.80	+ .10%
	...	" 4	" 13	...	15.95	16.02	— .07%

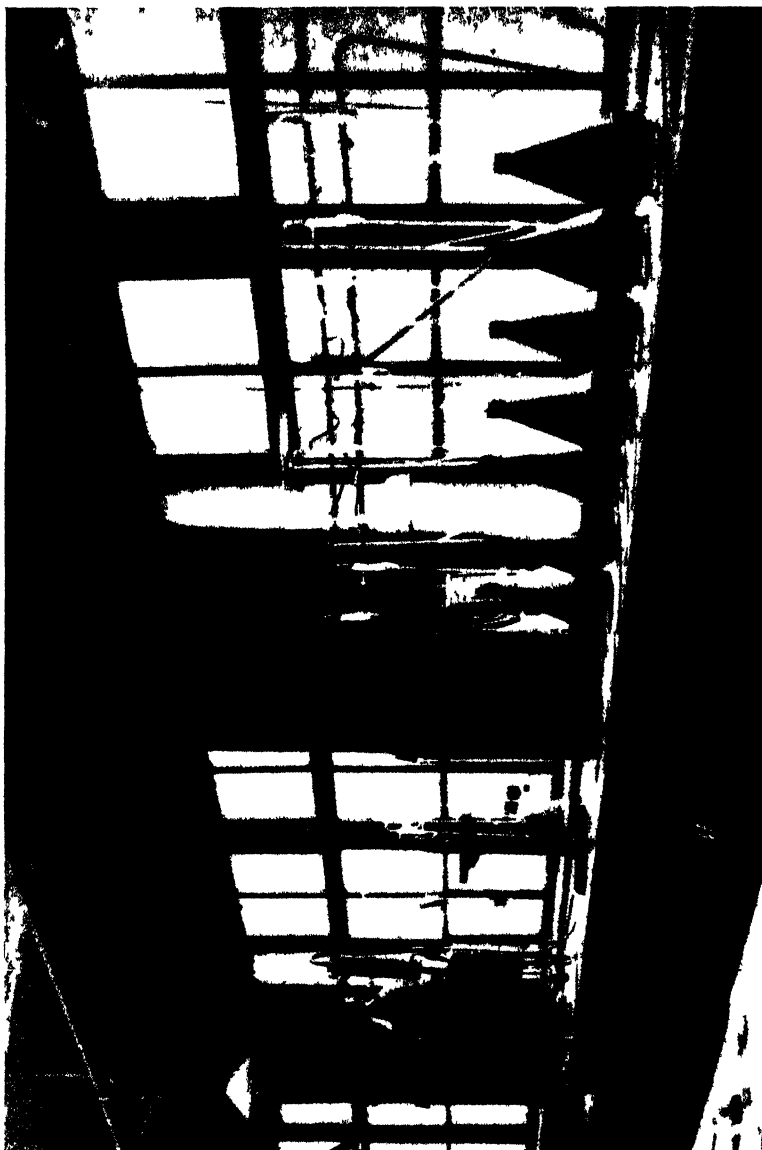


FIG 3

a given time thus allowing more precise control to be established over a material during processing as well as in its finished form. Actually, the new method is invaluable in allowing experimental studies of the influence of the regain of a material on processing to be carried out without interfering with the normal routine of the testing department.

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11—NOTE ON THE DETERMINATION OF ARTIFICIAL SILK (VISCOSE) IN MIXTURES OF ARTIFICIAL SILK AND COTTON WASTE

By P. MCGREGOR, B.Sc., F.I.C., and C. F. M. FRYD, B.Sc., A.R.C.S.

The analysis of mixtures of artificial silk and cotton in tissues and yarns usually presents little difficulty as the components can generally be separated mechanically by dissection. In garnetted mixtures of artificial silk and cotton waste the fibres are intimately mixed; mechanical means of separation is thus impossible, and chemical methods must be employed. No difficulty arises with mixtures of cellulose acetate and cotton, as cellulose acetate is readily removed and estimated by extraction with acetone; but, as artificial silk (viscose) and cotton consist fundamentally of cellulose, it has been difficult to find a reagent capable of effecting a quantitative separation, and until recently no satisfactory method of analysis has been available.

Lloyd and Priestley¹ devised a method of analysis which depends on the treatment of the mixture with sulphuric acid under specified conditions, whereby viscose is disintegrated into short lengths and subsequently removed by washing, while the cotton is practically unattacked. In many cases we have found this method satisfactory, but we have been unable to obtain consistent results with garnetted mixtures of artificial silk and cotton waste, or where the artificial silk is spun with other fibres to form a composite yarn.

Krais and Markert² published a method based on the use of calcium thiocyanate solution of a definite strength (100 grammes of the technical salt per 100 ml. solution; b.p. 120° C.) which dissolves silk and artificial silk but does not attack cotton or wool to any appreciable extent.

Williams³ investigated the action of concentrated calcium thiocyanate solution on cellulose (cotton and wood pulp). He demonstrated that cotton is completely soluble in calcium thiocyanate solution (b.p. 133°–150° C.) provided the solution is neutral or acid; if it is alkaline no solution of the cellulose takes place. The calcium thiocyanate appears to act as a hydrating agent, the cotton swells and finally is dispersed forming a colloidal solution. He found that the cellulose can be regenerated in fibre form by passing the solution through a fine orifice into a precipitating bath, 50–90% alcohol being found most convenient.

At first sight there does not appear to be any obvious reason for the fact that by the use of a less concentrated solution of calcium thiocyanate it is possible to effect a practically complete separation of artificial silk (viscose) and cotton. Consideration, however, of the modern conception of the constitution of cotton and viscose fibres as revealed by X-ray analysis leads to a possible explanation. The cotton fibre consists of long closely packed bundles (cellulose micelles) arranged parallel to the length of the fibre. The micelles are composed of rods (main valence chains) built up of 1–4 glucopyranose units. In regenerated cellulose, e.g. viscose, the micelles are smaller and are not parallel but orientated almost at random⁴. If it be assumed that the hydrating action of the calcium thiocyanate can be exerted only on the hydroxyl groups on the surfaces of the micelles, and that in viscose the number of hydroxyl groups available for attack is greater than in cotton, it is reasonable to infer that the more ready solubility of viscose is due, in part at least, to this cause.

We have investigated the method of Kraus and Markert using acidified calcium thiocyanate solution (see below) and are in general agreement with their findings that silk and all forms of artificial silk are completely dissolved, and that mercerised cotton, cotton and wool suffer only a small loss (2 to 3%). We have modified slightly the details of their procedure and are obtaining consistent results in the routine examination of artificial silk and cotton waste. Particulars of the reagent and method used by us are as follows.

Reagent

A commercial solution of calcium thiocyanate containing about 80 grammes Ca (CNS)₂ per 100 ml. Its boiling point should be observed and (a) if below 120° C. it should be increased to that figure by the addition of anhydrous calcium chloride (approximately 2 grammes per 100 ml. for every degree rise in temperature required) together with concentration if necessary, (b) if above 125° C. it should be lowered by dilution with water to 122–123° C.

The commercial solution is usually alkaline and must be rendered slightly acid to litmus by the addition of glacial acetic acid. (The solution we are using has a *pH* value of 2.1)

Method

One gramme of sample, which has previously been freed from oil and other extraneous matter and conditioned by exposure for 24 hours in an atmosphere of 60–65% relative humidity at ordinary temperature, is placed in a 250–300 ml. conical flask with 70 ml. of acidified calcium thiocyanate solution. The flask is then clamped securely in a water bath at a temperature of 70–80° C. and the contents stirred mechanically (approximately 400 revs. per minute) for 30 minutes. The contents of the flask are then filtered through a Jena glass filter crucible (Becker pattern 2 G.1) connected to an efficient suction pump, and the cotton residue pressed with a flat-ended glass rod. At this stage it must not be washed with water as this causes reprecipitation of the cellulose. The cotton is then replaced in the conical flask and the treatment repeated with a further 30 ml. of acidified thiocyanate solution for ten minutes. After filtration the cotton wad is removed, boiled for 30 minutes in two successive portions of distilled water, washed, dried in the oven, and weighed after being reconditioned for 24 hours.

The following typical results have been obtained by applying the method to prepared mixtures of artificial silk (viscose) and cotton.

	Percentage Artificial Silk (viscose) in mixture	Percentage Artificial Silk found	
1	75.0	75.3	75.4
2	70.0	70.5	70.0
3	60.0	60.3	59.4
4	50.0	49.6	49.8
5	25.0	25.3	24.6

We desire to thank Sir Robert Robertson, K.B.E., M.A., F.R.S., Government Chemist, for permission to publish this paper.

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12—AN INTRODUCTION TO THE MICRO-ANALYSIS OF YARN TWIST

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INTRODUCTION

A technique to clarify and supplement the usual mechanical analyses of yarn twist and structure is of considerable interest and importance. With the growing number of attempts to correlate the properties of strength and stretch in yarn with the structural conditions existing at the point of failure, some means for determining these conditions at closely spaced intervals without disturbance of the yarn is essential. The microscope when equipped with the proper accessories furnishes the necessary means. Proper treatment of the data thus provided gives the needful information.

Not only will a technique of this sort be of value for such work, but it will also make available a convenient means for inspection of yarns, and for the study of yarn and cord variation. A rational examination of the structural factors in single and plied yarns and an attempt to compare existing conditions with a theoretical or ideal condition will be described.

PREVIOUS WORK

Failure to recognise several factors involved in such an investigation has either minimised the value of, or led to error in, previous work.

Skinkle¹ gives a formula for determining yarn twist which is of the following form—

$$T = \frac{\tan A}{D}$$

where T=twists per inch

A=helix angle in degrees

D=yarn diameter in inches.

This entirely fails to take into consideration the helix effect and is derived trigonometrically from a plain triangle which has no real physical significance in the yarn structure.

Barker and Midgley² recognise the helix angle effect and base their trigonometric derivation upon a triangle which is a developed surface—the outer surface of the yarn. Their formula takes the form—

$$T = \frac{D}{\pi (\cot \beta)}$$

Where D is the reciprocal of the yarn diameter written as a whole number

T is the twists per inch

β is the helix angle.

The authors say "The above formula may be usefully employed for both single and two-fold yarns, but the cloth constructor should think clearly and carefully respecting the differences between the two."

As will be shown, the cases of two-ply and single yarns represent the extremes of variation in the correct use of a twist formula and cannot, by their very nature, be treated by the same identical equation. A further point to be considered here is the use of an approximate diameter, computed instead of measured. Wakefield's³ work in discussing the value of such a calculation has been either forgotten or else overlooked. J. A. Matthew⁴ shows how certain empirical expressions for "D" may be obtained and similar work has been undertaken, among others, by Woodhouse and Brand⁵

A modification of the formula by Barker and Midgley is derived by Herzog⁶ but is not generalised as is done in the following work by the author. Such treatment was outlined in part by Gurney and Davis.⁷ They use a value which they designate as the *mean diameter*. For a two-ply construction the value is assumed to be one-half the measured or nominal diameter. (D in Fig. 4.) Thus far the author is in agreement. But a statement that the ratio approaches two-thirds as the number of plies increases indefinitely is not correct. Gurney and Davis' derivation of the limit thus set forth is to be found in an earlier paper⁸ based on data obtained from investigations conducted by the present author in 1923 and by two students working under his direction in the following year. These data were confined to constructions less than and including 6-ply No. 7's cotton yarns and the semi-logarithmic plot as extended to higher plies by Gurney and Davis is not believed by the author to be reliable. Gurney and Davis⁹ state that, for a three-ply con-

struction, the value of the constant is $\frac{K}{\sqrt{3}}$; for a $\frac{3}{8}$ 23's tire cord the constant is K; and, for a single 23's yarn, the constant is $\frac{K}{\sqrt{15}}$ (where K= $\frac{3}{8}$ in every instance). They give^{9,7}, the following formula for helix angles—

$$\text{Cord helix angle} = \tan^{-1} K\pi (T_0) (D)$$

$$\text{Ply helix angle} = \tan^{-1} \frac{K\pi (T_1) (D)}{\sqrt{3}}$$

$$\text{Single helix angle} = \tan^{-1} \frac{K\pi (T_2) (D)}{\sqrt{15}}$$

Substituting average measured values from a $\frac{3}{8}$ 23's tire cord (see Table III) we have

$$\text{Single helix angle} = \frac{\frac{3}{8} (\pi) (6.9) (.036)}{\sqrt{15}} = 27.6^\circ$$

$$\text{Ply helix angle} = \frac{\frac{3}{8} (\pi) (10.2) (.020)}{\sqrt{3}} = 24.0^\circ$$

$$\text{Cord helix angle} = \frac{3}{8} (21.5) (.0073) = 22.8^\circ$$

The actual values as measured are 30.3, 28.2, and 24.5 respectively. It will thus be seen that Gurney and Davis' values decrease progressively but are in each case lower than the true values. It is shown mathematically in the

following treatment that a logical and rigid demonstration is possible and that the limit of the ratio is not 0.67 but 1.00. The concept of *mean diameter** as used by Gurney⁷ and Davis is discarded as having no rational meaning here, and *helix diameter* (d Fig. 4) is substituted. This term, when employed with the *nominal diameter* (D Fig. 4) of the yarn, yields a factor to be known as " k ," which is essential to a proper statement of the twist formula, as will be shown.

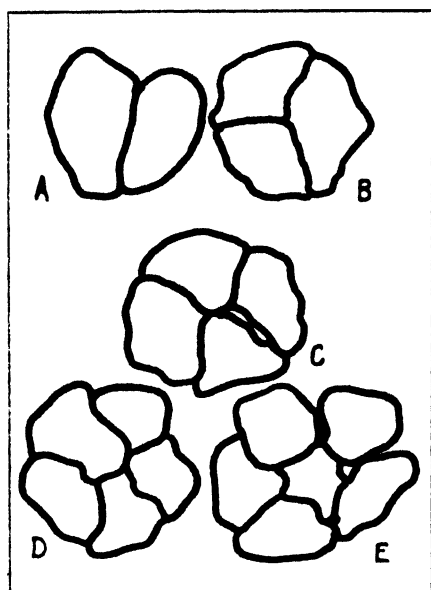


FIG. 3

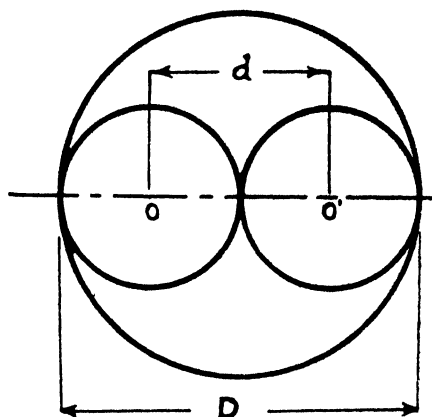


FIG. 4

Table 1

Authority	Cord Twist	Ply Twist as in Cord	Single Twist as in Cord
Twist Counter	6.9	10.2	21.5
Schwarz	7.5	13.6	25.5
Gurney and Davis ⁸	7.3	14.3	38.2
Gurney and Davis ^{7,9}	6.0	22.2	14.7
Barker and Midgley ⁴	4.0	8.6	25.5
Skinkle ¹	12.6	26.9	80.0

The above table shows the twist as actually measured by means of a Suter precision twist counter compared with the calculated values. It should be borne in mind that the values obtained by the author's formulae are based on theoretical values of " k " and therefore do not take into account the yarn deformation. It will be seen that the author's values are the only ones consistently approaching the measured twists. Where agreement exists between the author's results and those of another writer, it is because the same, or nearly the same, constant " k " was used by them.

* $\frac{D}{\sqrt{n_1}}$ and $\frac{D}{\sqrt{n_1 n_2}}$ where n_1 = number of ply in first ply.
 n_2 = number of ply in second ply.

SUMMARY

Theoretical yarn structure can be used as a guide for selection of a yarn for use. It may also be compared with the actual conditions to give information as to compactness, fibre density, and handle.

An important feature of the technique described is the possibility of measurement of the desired quantities with minimum or no alteration or destruction of the yarn.

A rational formula for the micro-determination of twist in single, plied, and cabled yarns is derived and its usefulness and limitations are pointed out.

Further, the relation of certain factors in this expression to the structure of the yarn is shown and the theoretical organisation of a range of plied yarns is given.

Finally, empirical methods for the determination of working values of an important factor in the formula for micro-twist analysis are described.

DISCUSSION

The density of the yarn is not the same as the density of the fibre—and, as Matthew⁴ points out, it may be only one-third as great. He also states and quotes experimental data in support of his contention, that the variation in yarn densities noted between flax and cotton, for example, must be accounted for by changes in the arrangement and packing of the fibres. Thus, however far we may pursue the spinner's rule ($T = c\sqrt{N}$), this one factor of density prevents any statement more than that the twist is proportional to the twist constant and inversely proportional to the yarn diameter—other factors being equal. Since the density and yarn diameter may be on occasion interdependent, this apparently simple statement is not as satisfactory as it seems.

Anticipating an empirical treatment of conditions, it will be wise to study the variation of twist from another angle, and to so select the method of attack that the density of neither fibre nor yarn will be involved. This may be done by means of an equation of the same form as the spinner's rule.

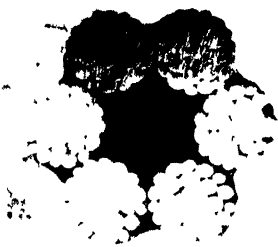
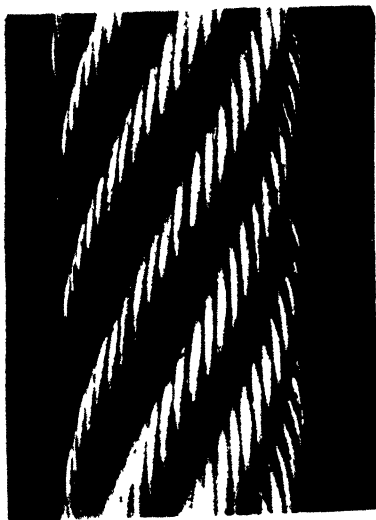
It is evident that

$$T = f(Q, D)$$

where Q is the helix angle of twist and D is the yarn diameter, both as measured. Just what form the function of Q and D should take will be apparent from the following study of a theoretical yarn. It will be assumed that such a structure is made up of units of circular cross section and of uniform diameter throughout their length. This assumption is an approximation, but because of the properties of a helix, and the nature of the mathematical discussion to follow, is not unjustified for the common range of angles. A right circular cylinder, when completely sectioned at an angle other than 90° , will yield an elliptical cross section if viewed parallel with its axis.

But the elements of even an ideal yarn are not right circular cylinders. They are helically arranged cylinders, progressing in three rather than two dimensions. Thus truly elliptical sections cannot result. Further, it can be demonstrated, for helix angles less than 30° , that the section shape is closely approximated by a circle.

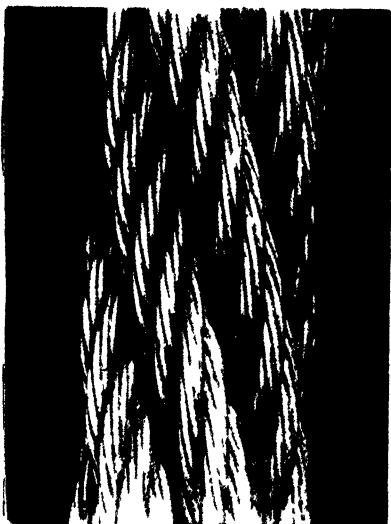
For angles greater than 30° , the distortion is circumferential and the radial width of section remains substantially unchanged at the point where the measurements called for in the following discussion are made. The circumferential distortion affects the value of the central angle, but this error is not



Q - 10

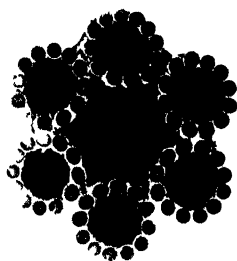
Fig. 1

Q - 24



$Q=17^\circ$

FIG. 2



$Q=19^\circ$

serious for angles less than 45° , particularly in view of the data of Table II.

Particular attention should be drawn to the changes in shape of the individual wires of Figs. 1 and 2. The circularity is perfectly maintained at the outside of the strands, but on the inside where the helix angle of the individual wire relative to the rope axis becomes greater than 30° a slight tangential distortion occurs. This has been taken into consideration in the discussion which follows on single yarns. The radial dimension remains unaltered and this is the important consideration.

Barker and Midgley⁹ state, for example, that a helix angle of 30° corresponds to a hard twist and that a helix angle of 45° represents normally an extremely high twist, and they print a nomographic chart by Dr. Brodsky which makes 45° its limiting angle. The author is in substantial agreement with this concept.

It follows, therefore, that the departure of the section shape from a circle will be slight for normal yarns.¹³ For visual substantiation, the reader is referred to Figs. 1 and 2 which are photographs by the author of wire rope, longitudinally and in cross section. An ideal structure of essentially circular elements will be studied as a basis for later measurement of yarn deformation. The deformation may sometimes result in sections which are approximately elliptical, semi-circular, or even circular sectors. (See Fig. 3.) Thus valuable bases for comparison with the empirical values can be obtained later.

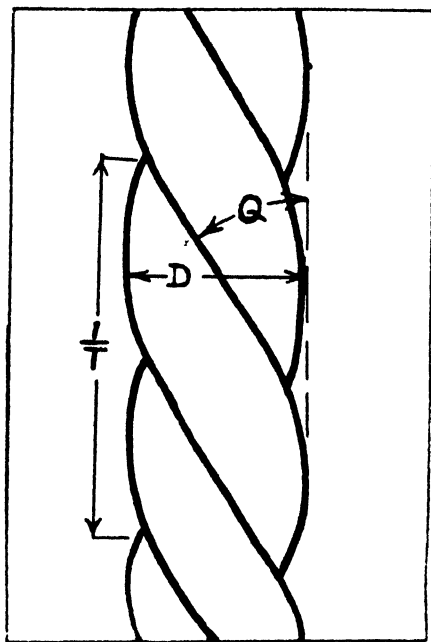


FIG. 5

Fig. 5 shows a diagrammatic, longitudinal view of such a yarn—which we shall assume for simplicity to be a two-ply structure. (The general case will be developed later.) If we designate the measured (nominal) yarn diameter by “D,” the helix angle by “Q” and the twist per inch by “T” respectively, we shall have the following dimensional data applying to one complete helix.

1/T will be the length in the plied yarn occupied by the helix, and is expressed as inches per twist. D is measured in inches by the microscope (Figs. 6 and 7) as will be described, and "Q" is, for convenience, taken as the angle between a tangent to one side of a single yarn and a line tangent to the outer curves of the plied yarn. If our initial assumptions are granted, then it follows that the line tangents will be parallel to the respective centre lines (themselves not easily determinable) of the single and plied yarns—and, therefore, "Q" is the true helix angle. This angle actually exists at the centre of the single yarn and an equivalent angle on the yarn surface is measured.

In Fig. 4, points "O" and "O'" are the loci of this helix in cross section, and their separation is measured by the distance "d" called the *helix diameter*. In any yarn $d = F(D)$ and for a two-ply yarn, the constant of proportionality is 0.5, so that we may write—

$$d = k(D) \text{ where } k \text{ is } 0.5 \text{ for a two-ply yarn.}$$

Now $k = f(n)$ where "n" is a number of units involved in the construction. (The quantity will be more definitely defined in what follows.)

To derive the relationship, refer to Fig. 8. Here the circle ABC with centre "o" represents the core of a theoretical plied yarn and may contain as many units (single yarns) as desired. The ideal structure will be surrounded by a complete ring of units, tangentially arranged, several of which are shown. In the figure thus obtained, draw OG through the centre (D) of any one of the units of this outer ring. OG will cut the core circle at a point A. Draw also OJ through the centre F of the next adjacent unit. Let OJ cut the circle representing the limiting boundary of the core at C. Designate the point of tangency of the two adjacent units selected as E. Draw OE and produce it to H, letting it cut the core circle at B. Draw DF.

Now, by plane geometry,

DF will pass through E and will be perpendicular to OH at this point.

Thus the triangle OED is a right triangle.

Denote $\angle AOB$ as β

$$\text{Now } OD = \frac{DE}{\sin \beta}$$

DE is the radius of a unit circle and as such will be written as "r". Similarly, OD is the radius of the circle passing through the centres of the outer unit ring and will be denoted as R_0 .

$$\text{Thus } R_0 = \frac{r}{\sin \beta} \dots\dots\dots (1)$$

$$\text{Further } OG = OD + DG = R_0 + r$$

and, if we call R the radius of the plied yarn, we have—

$$R = R_0 + r$$

$$\text{and } R = \frac{r}{\sin \beta} + r \dots\dots\dots (2)$$

$$\text{By definition, } k = \frac{R_0}{R} \dots\dots\dots (3)$$

Substituting (1) and (2) into (3) we have, after reducing—

$$k = \frac{1}{1 + \sin \beta} \dots\dots\dots (4)$$

From Fig. 8 $\beta = \frac{360}{2n} = \frac{180}{n} \dots\dots\dots (5)$

where n is the number of units in the outer ring.

Substituting (5) into (4) gives—

$$k = \frac{1}{1 + \sin \left(\frac{180}{n} \right)} \dots\dots\dots (6)$$

If we now study the variation of this equation, which is evidently the form of the function which was required, we may write—

$$\text{Lim}_{(n \pm \infty)} \left[\frac{1}{1 + \sin \left(\frac{180}{n} \right)} \right] = 1$$

This is the same as saying that for a yarn of an infinite number of plies, the value of “ k ” will be unity. Since a single yarn may be considered as approximately a high plied construction in which the individual fibres correspond to the single yarns, it will be apparent that “ k ” will be only slightly less than unity. That it will not be a constant quantity for all single yarns can be understood when it is realised that quite a different value would be expected for a high counts yarn made of relatively few fibres as compared with a coarse yarn containing many fine fibres. Particularly is this true of rayon yarns. Further analysis will show applications.

When making use of formula (6) great care must be taken to avoid confusing the value of “ n ” with the number of plies in the yarn. If “ N ” is taken to indicate the latter quantity we may establish a relationship between “ n ” and “ N ” which, while not without flexibility, will nevertheless be of considerable value in interpretation of yarn structure. In Table II, the derivation of which follows, the theoretical structures are listed.

Referring again to Fig. 4 we see that

$$\frac{r}{OD} = \sin \beta$$

Also $OD = OA + r$

Substitution gives $\sin \beta = \frac{r}{OA + r}$

For a unit circle, r can be considered equal to 1.

Then $\sin \beta = \frac{1}{OA + 1}$

and $OA = \frac{1}{\sin \beta} - 1$

To determine how many units occupy the core and which must be added to those units comprising the outer ring, “ n ” in number, to give the ply “ N ” of the yarn, consider Fig. 8.

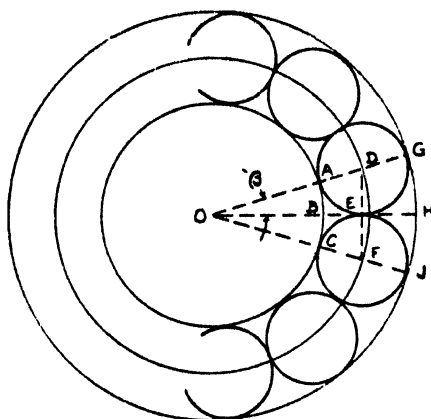


FIG. 8

OA is the radius of the core, and in order that this space may be occupied by one unit it must be at least equal to "r" in magnitude. From plane geometry it will be apparent that for two, three, four, and five-ply constructions there will not be room for a unit core; while for a six-ply there will be just enough room at the core for a single unit. This may be demonstrated mathematically as follows—

$$\text{Let } n=5 \quad \beta = \frac{180}{n} = \frac{180}{5} = 36^\circ$$

Substituting

$$\begin{aligned} OA &= \frac{1}{\sin 36^\circ} - 1 \\ &= 1.701 - 1 = 0.701 \\ 0.701 \text{ is less than } 1.000 \end{aligned}$$

Let $n=6$

$$\begin{aligned} \beta &= \frac{180}{6} = 30^\circ \\ OA &= \frac{1}{\sin 30^\circ} - 1 \\ &= 2 - 1 = 1 \end{aligned}$$

Similarly, the value of "OA" can be computed for any assumed value of "n." Eventually "n" will reach a magnitude such that "OA" will become equal to or greater than the radius of the circle which circumscribes two tangent circles. Evidently such a radius would be—

$$\frac{1}{\sin \left(\frac{180}{n} \right)} + 1$$

and when $n=2$ this expression reduces to 2.

For a value ($n=9$), OA becomes 1.92, while for ($n=10$), OA becomes 2.23. Theoretically there would have to be 10 units in the outer ring before a core of two units could be formed, but practically the value of 1.92 is so

close to 2.00 that an 11-ply yarn could easily have a two-unit core. The author during the micro-examination of cross sections of 11-ply yarns has repeatedly seen this condition. As can be seen, it gives a flat yarn. We are concerned here, however, only with the theoretical construction.

It will also be seen that for a three-unit core, the value of OA must be at least 2.55. Hence, before such a core can theoretically be formed, " n " must reach a value of 11. This gives a value of 2.57. The close agreement here is indicative that a 14-ply yarn consisting of three units in the core, surrounded by 11 units would be a symmetrical structure and not liable to serious distortion under normal conditions.

When " n " reaches a magnitude sufficient for a core of more than six units, the theoretical structure resolves itself into a core surrounded by two or more concentric rings. Thus, if we let $n=13$, we obtain a value of $OA=3.18$. A new core OA' to go with this would have a numerical value of 1.18, and in such a space there is room enough for a single unit. The construction is, therefore, a 20-ply yarn made up of a single unit core circumscribed by six units and the whole surrounded by 13 units.

The same method can be extended for more and more complex cases. A possible construction for a theoretical 50-ply yarn, such as would be employed for certain classes of camel hair belting, would then be a core of one unit surrounded by a ring of 10 units, surrounded by another ring of 16 units, the whole surrounded by an outer ring of 23 units. That this yarn must of necessity be distorted is evident when it is considered that there would be room for two more units at the core. Thus a 52-ply yarn is a better construction because it will be distorted less under normal conditions.

Study of Table II shows that certain constructions are inherently badly corkscrewed. That is, they contain unit cores. The yarn forming such a core must be shorter in length than those which twist about it, hence, when the plied yarn is strained, the core takes the load first and often ruptures before a breaking strain is reached in the outer units. Such a yarn is evidently weak. It has been shown that a seven-ply yarn is such a construction, as are also eight and nine-ply. These latter however, are almost certain to be flattened and thus the core effect is minimised. Yarns of 20-ply through 25-ply are weak, as are yarns of 40, 42, 43, 46, 48, 49, and 50-ply construction.

Since both three- and five-ply yarn are fairly stable combinations (the latter less so than the former), it is often of advantage to cable yarns of multiple units rather than to ply them. A 15-ply yarn for example, is not a particularly good construction. It consists of a core of four units (a most unstable combination) and an outer ring of 11 units. The load will first come on the four-fold core when the yarn is strained, and after this has failed, the remaining 11 strands take the stress. A better combination—and one which is widely used for tyre cords—is made up of three five-ply yarns cabled together. If tension and yarn sizes during manufacture are controlled and maintained uniform, such a construction will not be corkscrewed. Consideration of the theory just advanced in the foregoing will show that this organisation is somewhat better from the standpoint of stability than would be a series of five three-ply yarns cabled together.

It is well to point out here that constructions having multiple cores, while still corkscrewed in the strict sense of the term are, nevertheless, better than those made up with unit cores. The reason is that in addition to the

sharing of the early stages of the load by a number of strands rather than one alone, the core, by reason of its twist, necessarily possesses a greater degree of stretch than would a single unit. This, of course, is due to the "helical spring" effect familiar to all testers of twisted yarns.

Table II

Comment on Yarn Structure with Certain Alternative Arrangements	Apt to be Distorted	Very Stable	Unstable	Stable	5001	Corkscrewed	Corkscrewed	Corkscrewed, 7002 (non-symmetrical)	Flat—Room for one more unit in core
Ply ... 1	2	3	4	5	6	7	8	9	10
n outer ring 1	2	3	4	5	6	6	7	8	9
1st inner rg. 0	0	0	0	0	0	0	0	0	0
2nd inner rg. 0	0	0	0	0	0	0	0	0	0
Core ... 0	0	0	0	0	0	1	1	1	1
k _t ... 1.00	0.50	0.54	0.59	0.63	0.67	0.67	0.70	0.72	0.75

Comment on Yarn Structure with Alternative Arrangements	Flat two-unit core	Flat—9003 Room for three-unit core	Stable	Flat—10004 Room for four-unit core	Oval—Four-unit core is Unstable	Flat—Room for five-unit core	Stable Yarn	Very Flat Room for six or seven-unit core	Somewhat Flat—Room for seven-unit core	Corkscrewed
Ply ... 11	12	13	14	15	16	17	18	19	20	
n outer ring 9	10	10	11	11	12	12	13	13	13	
1st inner ring 0	0	0	0	0	0	0	6	6	6	
2nd inner ring 0	0	0	0	0	0	0	0	0	0	
Core ... 2	2	3	3	4	4	5	5	0	1	
k _t ... 0.74	0.76	0.76	0.78	0.78	0.79	0.79	0.81	0.81	0.81	

Comment on Yarn Structure with Certain Alternative Arrangements	Flattened Room for eight-unit core	Somewhat Flattened—Room for eight-unit core	Flattened Room for nine-unit core	Flattened	Very Flat Room for 11-unit core	Somewhat Flat—Room for 12-unit core	Very Flat Room for 13-unit core	Flattened Room for three-unit core	
Ply ... 21	22	23	24	25	26	27	28	29	30
n outer ring... 13	14	15	15	16	16	16	17	17	17
1st inner ring 6	7	7	8	8	9	9	9	10	10
2nd inner ring 0	0	0	0	0	0	0	0	0	0
Core ... 1	1	1	1	1	1	2	2	2	3
k _t ... 0.82	0.82	0.83	0.83	0.84	0.84	0.84	0.85	0.85	0.85

Further examination of this table shows that for a yarn made up to 150 units, the value of "k" is 0.88. While this approaches unity more nearly than previous values noted, it will only reach it when an infinite number of units are reached. For rayon yarns, certain fine worsted yarns, etc., there may be from 30 to 150 or more fibres or filaments present. In the latter case, "k" might be computed if "n" were known. To determine "n", however, is a somewhat lengthy process. A better method is to make a cross section of the yarn (a paraffin mount—Viviani cork method—or the Schwarz metal slide method¹¹) and count the number of units in the outer layer or ring. A simple substitution in equation (6) gives "k" directly.

As an alternative method, "k" may be computed from direct measurements of the sample without the necessity of making a cross section. Since, in a single yarn, the units of the various layers are the fibres, the value of "r" is

evidently the fibre radius. Now a ratio of diameters may be taken just as well as a ratio of radii, and if this is done, we have—

$$k_s = \frac{D-d}{D} \dots\dots\dots(7)$$

where

k_s is the empirical helix constant

D is the yarn diameter

d is the fibre diameter.

Both D and d should be the averages of a number of measurements and should be expressed in the same units.

One precaution must be observed. If the fibres are not circular or nearly so in section, but are oval as for certain wools,¹³ for ramie, and Italian hemp; or reniform as for certain rayon and cotton; it will be found that the examination of a cross section should be made. If the majority of the fibres lie as in Fig. 9, the long diameter should be taken, while if they lie as in Fig. 10, the short diameter should be measured. In longitudinal mounts of the yarn, it will be impossible to measure the diameter of the fibre which is orientated in a radial position.

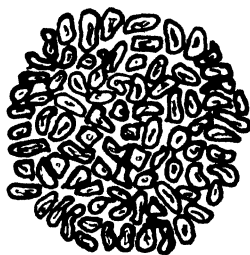


FIG. 9



FIG. 10

In many cases, notably for single cotton yarns, the sections of the single fibres are arranged in random order. It would seem advisable in such a case to take the average of the long and short diameters of a number of fibres for the working value of " d ." In the case of a 50's cotton yarn recently tested in this manner it was found that the average long diameter was 7.64 ten-thousandths of an inch while the average short diameter was 4.00 ten-thousandths of an inch. This gives an average diameter of 5.82 ten-thousandths of an inch for the fibre. The mean diameter of the single yarn was 54.5 ten-thousandths of an inch and the yarn contained 26.7 twists per inch. The helix angle was found to be 23° and substitution in formula (8) (to be derived) yields a value of " k " of .927. If the values of yarn and fibre diameters just noted are substituted in equation (7) the result will be very closely 0.9.

Further analyses by Stockwell¹² indicate that as " n " increases the formula becomes more and more reliable and is very satisfactory indeed for ordinary single yarns. In the case noted above " n " = approximately 50 and if the analysis of Table II were continued to this point a value of " k " slightly above 0.9 would be obtained.

Some idea of the distortion which may have taken place in a plied yarn may be gained by locating the centres of gravity of the units in the outer layer and measuring their respective distances from the centre of the plied yarn. The average of these distances, when subtracted from the plied yarn

radius, and this difference divided by the latter quantity, yields a value of " k_s ," which may be less than, equal to, or greater than " k_t ," *

If " k_s " is less than " k_t ," the units must be nearer the centre than in the theoretical case, and the yarn is closely packed, or dense, in proportion to this difference. Three- and four-ply yarns formed of soft twisted singles frequently exhibit cross sections similar to those of the micrographs of Fig. 3. In the case of Fig. 3B, the value of " k_s ," is 0.45, while " k_t " is 0.55.

$$\text{Thus } \frac{k_t - k_s}{k_t} = \frac{0.10}{0.55} = 0.182$$

or 18.2 per cent.

In many cases the units composing such a deformed yarn are very closely circular sectors and the centre of gravity of such a sector is given by the relationship

$$Ro = \frac{R \sin \beta}{\beta}$$

where

Ro is the radial distance of the c.g. from the centre of the plied yarn.

R is the plied yarn radius.

β is one-half the centre angle subtended by the sector expressed in radians.

If " k_s " is equal to " k_t ," the yarn corresponds in structure to the theoretical case.

If " k_s " is greater than " k_t ," the yarn must be very loosely compacted. With the apparatus of Fig. 6 a value of " k_t " = .60 was obtained for a loosely twisted three-50's and as the twist was increased " k_s " decreased fairly steadily. From a study of the data it was apparent that the decrease in the plied yarn diameter was a more important factor than was change in the single yarn diameter.

The apparatus of Fig. 7 designed by the writer and built under his direction enables the investigator to insert or remove known amounts of twist into single or plied yarns while they are held in position on the stage of the microscope. By means of suitably arranged drums, the circumference of each of which is exactly one inch, a controlled and constant dead weight tension may be applied along the axis of the yarn and at the same time provide facilities for the measurement of elongation or contraction to the nearest 1/100th of an inch as either may occur. Illumination may be in the ordinary fashion from above the stage obliquely; but a very convenient arrangement particularly for fine yarns is provided in the new Leitz Ultropak system as shown in the Figure. Here the use of the goniometer ocular to which reference will later be made is shown.

Having studied the derivation of " k " by both the theoretical and empirical methods, we now pass on to an analysis of the twist formula itself. The rational form for this is evidently—

$$T = \frac{\tan Q}{\pi k D} \dots\dots\dots (8)$$

where

T is the twist per inch.

Q is the helix angle in degrees.

k is the helix constant.

D is the yarn diameter in inches.

*The theoretical value as given in Table II.

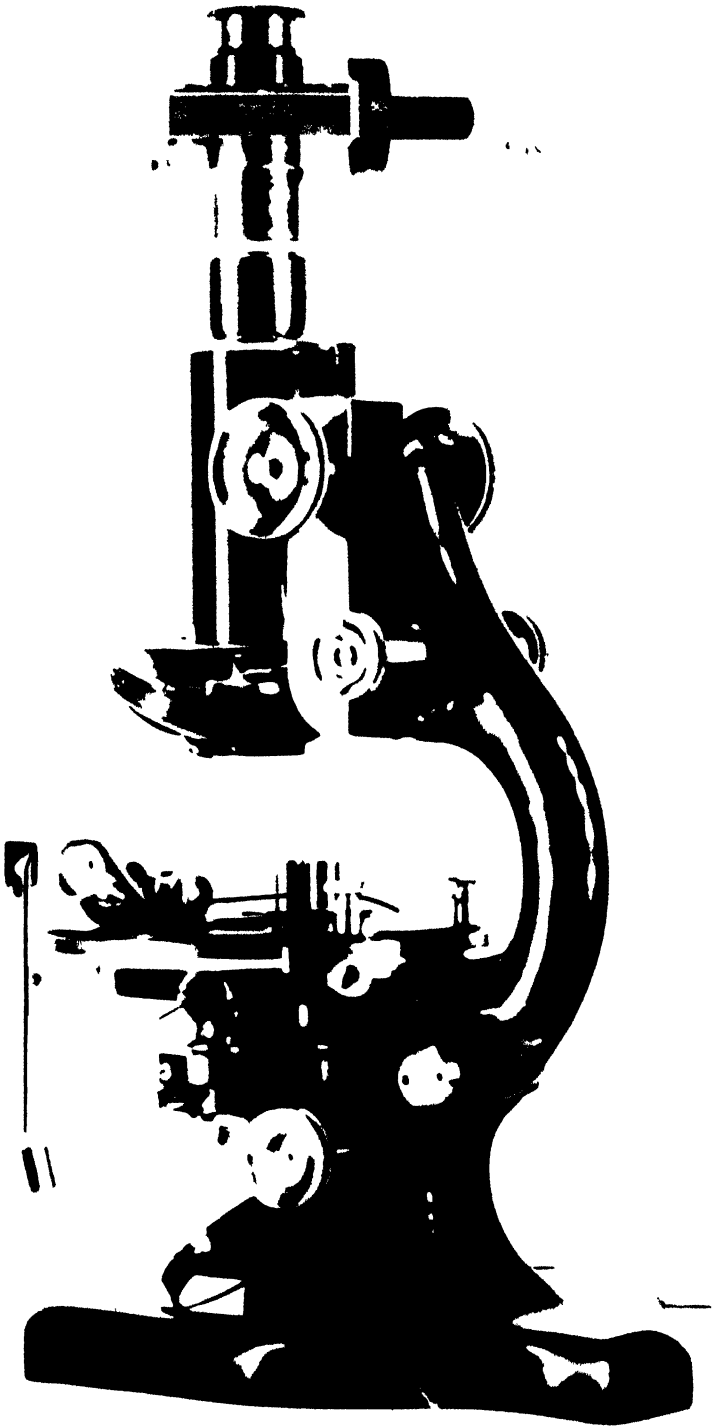


FIG. 6

Textile Microscope ready for insertion of proper objective.
Note Filar Micrometer and Special Yarn Holder.

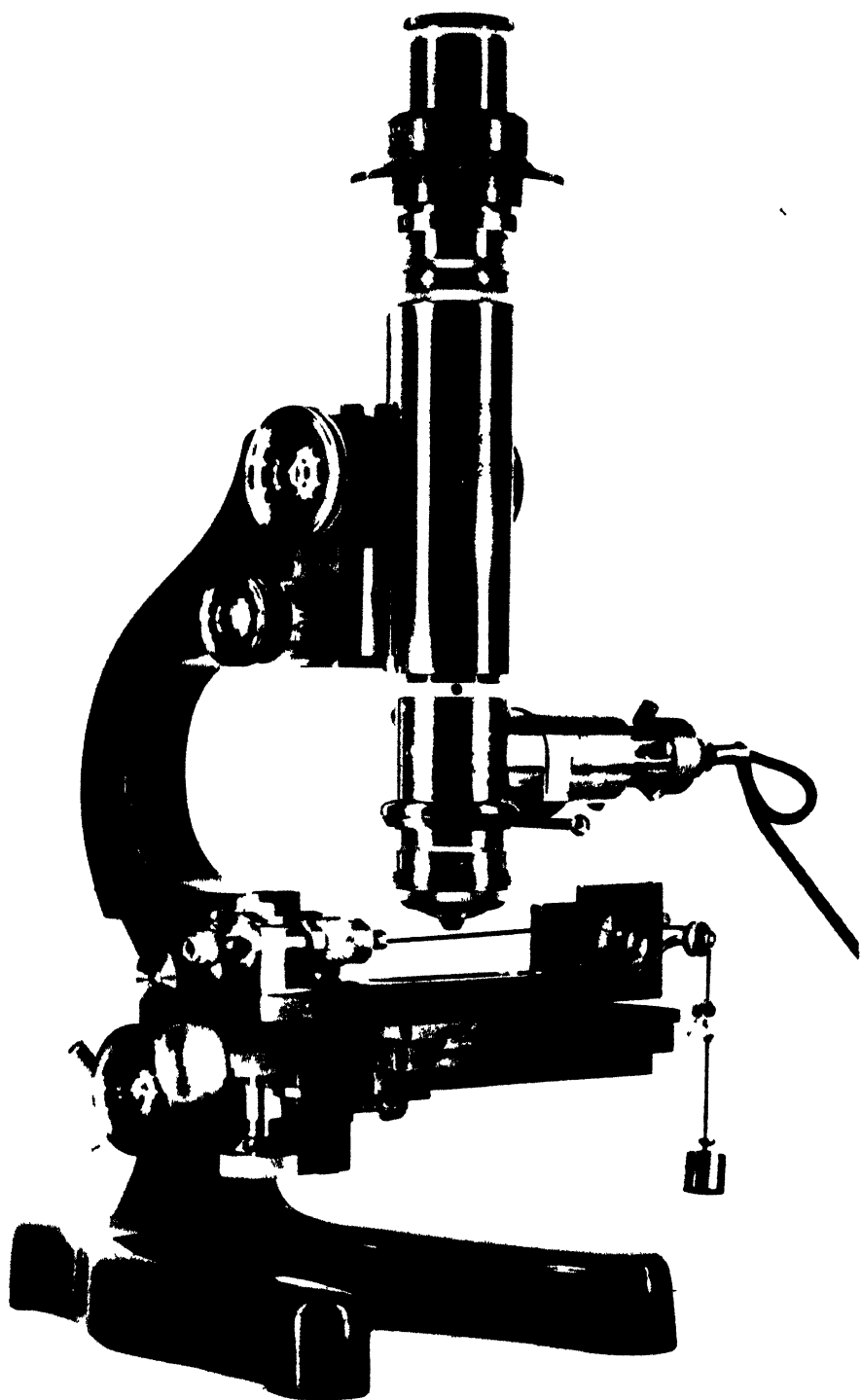


FIG 7

Note Goniometer Ocular and Micro Twist Test 1

In the light of the foregoing, we may determine " k_i " quite readily, and knowing this value for any given case, it is only necessary to measure Q and D .

Several methods are available. One of the most satisfactory is to employ a microscope equipped with a rotating stage graduated in degrees and readable to the nearest half degree at least, and with a filar micrometer ocular which has been carefully calibrated. A slide can be built to carry the yarn under any desired tension and may take as simple a form as Fig. 6 would indicate. This is a very efficient device designed by the author and used by himself and in class work for twist measurements.

With the yarn in position and a 32-mm. objective (not shown) on the microscope, the instrument is sharply focussed on the surface of the yarn, so that the average direction assumed by the fibres may be clearly seen. The angle of illumination can be so adjusted by shifting the light source as to make the definition good. Just sufficient light should be directed up through the stage opening from the substage mirror (in the absence of the condenser which is not needed) to illuminate the scale of the filar micrometer. Set the rotating stage of the microscope to zero, and turn the filar micrometer until the traversing cross hair is parallel to the fibres—as closely as can be estimated. Leave the filar micrometer in this position, held by its set screw.

Focus on the edge of the yarn and rotate the stage, at the same time traversing the movable cross hair of the filar micrometer, until it is tangent to one edge of the yarn at three points. Read the micrometer scale and record the reading. Read and record the angle indicated on the stage vernier. Now traverse the cross hair to the opposite side of the yarn and to a similar position of tangency. Read the micrometer scale. The difference between the two filar scale readings is the plied yarn diameter. If the stage has had to be rotated (which will not ordinarily be the case) in order to achieve the second position of tangency, the new angle should be read, and averaged with the first in order to get a corrected value. The result is angle A and is the angle between the fibres and the plied yarn axis. Return the traversing hair of the filar micrometer to a position tangent to one of the single yarns at a point near the centre of the plied yarn. Read the angle indicated on the stage vernier (B), and the filar scale reading. Traverse the filar cross hair to a position of tangency at the opposite side of the single yarn, and a second reading of the filar scale, when compared with the first, will give the single yarn diameter.

The angles desired for use in computing the twist per inch may now be calculated. Angle B is the angle between the fibres and the single yarn, while either $A + B$ or $B - A$ will be the angle between the single and the ply depending upon whether the fibres are inclined to the same or opposite sides of the plied yarn centre line as the single yarn axis respectively. Table III shows data for three-five 23's tire cord determined microscopically.

If a graduated rotating stage is not available, and if no filar micrometer is at hand, a camera lucida enables the investigator to draw a sketch showing the required angles and diameters. Use of a stage micrometer makes measurement of the diameters possible, and the draughtsman's protractor can be used to measure the angles. Skilful handling of illumination is essential, and on the whole, the method is not so precise as the technique calling for a filar micrometer.

Table III

Test	Cord Diameter inches	Ply Diameter inches	Single Diameter inches	Cord Helix Angle degrees	Ply Helix Angle degrees	Single Helix Angle degrees
1	·0339	·0182	·0068	25·0	26·5	31·0
2	·0337	·0186	·0070	25·5	28·5	24·0
3	·0372	·0163	·0068	23·3	26·5	30·5
4	·0342	·0185	·0061	26·0	23·5	30·0
5	·0359	·0193	·0061	23·3	31·0	28·0
6	·0346	·0213	·0066	24·5	30·6	31·5
7	·0353	·0198	·0094	26·6	28·0	35·0
8	·0373	·0210	·0083	24·6	31·5	27·5
9	·0369	·0232	·0071	24·3	34·6	34·3
10	·0391	·0206	·0086	21·5	21·5	31·0
Avg.	·0358	·0197	·0073	24·5	28·2	30·3

Various forms of goniometer oculars are available. The readings of angle obtained from any but the expensive types are not particularly precise, nor are the ocular micrometer scales convenient to use.

Experimental work conducted in the Textile Microscopy Laboratory of the Massachusetts Institute of Technology by the writer to date indicates strongly that the optical measurement of single yarn twist is in most cases much to be preferred over other methods.

For plied yarns twist can most precisely be measured in a properly designed mechanical twist counter. Optical measurements involving as they do a somewhat variable factor " k " are of value largely in conjunction with the mechanically measured twist to indicate yarn structure and deformations. This is a field of investigation in which little work has been done but in which experimental endeavour is considered by the writer to be well justified. It is proposed to continue this work intensively.

The writer has long believed that the only way to intelligently study yarn structure of any kind is to really see it in as much detail as possible. He therefore hopes that the foregoing discussion may awaken further interest in the subject and lead to development of new and improved forms of optical equipment.

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13—THE SULPHUR CONTENT OF WOOL. PART IV. FURTHER EVIDENCE OF THE VARIABLE SULPHUR CONTENT OF WOOL

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The inherent variation in the sulphur content of wool keratin has been clearly established in earlier papers^{1, 2, 3}, but in view of the conclusion of Marston⁴, that the sulphur content of wool is constant, it was considered advisable to carry out further work on this question.

This paper deals with two lines of evidence both of which substantiate the authors' original conclusions.

- (1) A comparison of the sulphur contents of wools purified by the methods of Marston and of the authors.
- (2) The results obtained from an examination of a series of Scotch wools.

Sulphur Determinations on Wools Purified by the Method of Marston and of the Authors

From previous work on different wools a small series was selected which represented different types of wool keratin. The wools were adequately sampled (see experimental part) and then purified.

The essential feature of the Marston method of purification is that after removal of fat and foreign matter from the wool, it is treated with 0.01 N hydrochloric acid and in this process "It is not infrequent to find variable amounts of sulphates in the washings from this fraction, this sulphur being presumably bound in salt formation to the fibre, as no detectable hydrolysis occurs at this reaction." This has not been the experience of the authors. The results of this comparison are given in Table I, and details of the methods used will be found in the experimental part.

Table I

Wool	Purification by Marston's Method			Purification by Barritt and King's Method		
	Sulphur on Wet Weight %	Regain %	Mean % Sulphur on Dry Weight	Sulphur on Wet Weight %	Regain %	Mean % Sulphur on Dry Weight
Welsh Wool No S 64 Shoulder	3.38, 3.38	15.87	3.92	3.42, 3.38	16.93	3.97
Welsh Wool Ram W. 44 Shoulder	3.49, 3.52	16.04	4.07	3.47, 3.42 3.38, 3.46	16.78	4.07
Welsh Wool X 40 Shoulder	3.17, 3.15	17.12	3.70	3.14, 3.16	16.90	3.68
Romney Corriedale Section 7	2.65, 2.63 2.62, 2.63	15.82	3.04	2.52, 2.50 2.53, 2.55	16.94 17.02	2.94 2.97
Australian Merino	3.07, 3.05	12.09	3.43	2.97, 2.99 2.99, 3.00	12.32	3.35

It will be evident from these data that the sulphur content of wool is inherently variable and that the method of purification has no great influence on the amount of sulphur found.

Apart from the treatment with the dilute hydrochloric acid, the procedure adopted was precisely the same for all the samples, so that even granting the possibility of some standard error (which if existing must be very small) it is difficult to imagine how such widely differing values of sulphur content as those for the Romney Corriedale and say the Welsh wools could possibly be obtained if the sulphur content of the wool were constant. It should be noted that the wools studied by Marston were all Australian wools though of different types. The authors, however, have analysed many different Australian wools which were found to possess varying sulphur contents² though the range of variation is not so wide as when some of the English and New Zealand wools are included. It would have been easy to extend the number of wools, but it is felt that sufficient has been said in previous papers^{1, 2, 3} in addition to this further evidence to establish most definitely that the sulphur content of wool is variable.

Experimental. The Marston—Barritt and King Comparison

The greasy wools were separated into locks, the loose wool removed from the base and three fractions were obtained by taking every third lock (i.e. fraction one contained 1, 4, 7 . . . fraction two, 2, 5, 8 . . .)

The samples were then pulled out by hand, thoroughly mixed, degreased with benzene, air dried, combed, benzened, air dried, washed off in numerous changes of distilled water and air dried as described in detail in Part I of this series.¹

It should be noted that Marston degreases with ether and alcohol, but owing to the penetration of the fibre by alcohol, and the subsequent difficulty of removal, it was considered preferable to use benzene. In any event this stage is not the crucial one in the difference between the two methods.

One fraction was then treated with 0.01 N hydrochloric acid (100 cc./gm. of clean wool) for 12 hours at room temperature after which it was washed with ten changes of distilled water and air dried. Soluble sulphate could not be detected in the dilute hydrochloric acid or in the washings, and further after concentration and oxidising no trace of sulphate was detected.

The two fractions were allowed to condition and samples weighed off for determination of sulphur and moisture content by the methods described previously.

Examination of a Series of Scotch Half-bred Wools

The authors have been fortunate in having access to a series of Scotch half-bred wools, which have been the subject of experimental work at the Rowett Research Institute by Messrs. Fraser and Roberts, and they are much indebted to Mr. J. A. F. Roberts (formerly of this Association) for the supply of samples and for the figures giving the change in fineness of the samples from base to tip.

The sheep involved in this nutritional experiment were divided into various groups, and were fed on a basal diet with addition of supplements.

On examination of the fleeces a definite "break" or weak place in the staple was found in a number of the samples coincident with the change in diet. On holding the lock at each end, a gentle pull separated it into portions designated "base" and "tip" fractions. This paper is not concerned with the significance of the nutritional factors involved which will be discussed in a forthcoming paper by the above-mentioned authors. Also the figures relating to changes in fineness are only inserted as indicating the imposition of

the changed conditions which have been accompanied in most cases by a change in sulphur content.

The examination, however, of the sulphur values obtained indicates clearly the inherent variations from wool to wool in the same and different groups, and particularly the ensuing variation (e.g. No. 188 V.) between base and tip portions, which latter phenomenon was first indicated in the case of typical wool samples in Part II of this series.

Table II

Reference Number of Sheep	Sulphur Content on Dry Weight %			Average Increase (+) or Decrease (—) of Fineness of Base over Tip* %
	Total lock	Tip	Base	
112 I	3.59	—	—	—
146 I	3.47	—	—	—
150 I	3.70	—	—	—
153 I	3.63	3.41	3.73	+31.7
175 II	—	3.54	3.79	- 3.0
122 III	—	3.17	3.39	+35.7
117 IV	3.64	—	—	—
120 IV	3.42	—	—	—
182 IV	3.62	—	—	—
183 IV	3.39	—	—	—
191 IV	3.47	—	—	—
130 V	—	3.68	3.68	+69.7
176 V	—	3.46	3.69	—
188 V	—	3.31	3.82	-17.2
118 VI	—	3.45	3.49	+4.5
132 VI	—	3.35	3.54	+46.5
160 VI	—	3.36	3.18	+120.9
187 VI	—	3.22	3.49	+9.3
189 VI	—	3.39	3.71	—
179 VIII	—	3.30	3.39	+28.0

* The fineness measurements are expressed in cms. of fibre/milligram, and it must be remembered therefore that the actual diameters of the fibres vary inversely as the square roots of their fineness.

EXPERIMENTAL

The gross samples were taken from the shoulder in all cases and locks removed in random fashion, sufficient being taken to give adequate sampling. The samples were then worked up in the usual way, and sulphur determinations made as described previously.

ACKNOWLEDGMENT

Mr A. N. Davidson has ably assisted in the experimental work.

REFERENCES

- ¹ Barritt and King *J. Text. Inst.*, 1926, **17**, T394
- ² Barritt and King *Ibid.*, 1929, **20**, T151
- ³ Barritt and King *Ibid.*, 1929, **20**, T159.
- ⁴ Marston Bulletin No 38, C C S I R, Australia, 1928

14—TEST FOR CHEMICALLY DAMAGED COTTON FIBRES

By J. W. LEWIS, M.Sc.

[The following test for detecting damage due to acid or over-bleaching in cotton fibres was worked out in this Laboratory some years ago by Mr. J. W. Lewis, and has since been frequently used for distinguishing between chemical and mechanical damage. It is particularly useful for the examination of the fibres surrounding small holes in a fabric.—R. S. WILLOWS.]

Small pieces of fibres are teased out gently on a microscope slide, care being taken not to damage the fibres with the needle, and are covered with a cover slip. A few drops of sodium zincate are run under the cover slip, the fibres left for a few minutes till swelling is complete, and any excess liquid soaked off the slide with filter paper. A few drops of water are then placed on the slide at one side of the cover slip, and are drawn underneath by filter paper placed at the other side. Care is needed at this stage, as the water has a tendency to run round the cover glass, and the fibres must be washed substantially free from zincate if the full effect is to be obtained.

It will be seen that—

- (i) In perfect or mechanically damaged fibres, such as unscoured sliver, the hairs are quite definite in outline, the cuticle entirely undamaged, and the ends bulged to a dumb-bell shape, as in the test given in *Jour. Text. Inst.*, 1922, 13, 240T.
- (ii) In fibres very slightly damaged, such as those in a normally bleached fabric, most of the fibres appear as in (i), but a few are a little more swollen, less definite in outline, and their ends less clearly dumb-bell shaped.
- (iii) In fibres sufficiently damaged as to cause weakness or holes in the fabric, the fibres are very much swollen, the edges and ends blurred, and some fibres partially dissolved.

In bad cases, the fibres almost entirely dissolve, leaving a shapeless mass of partially dissolved cellulose on the slide. See Plate I, Figs. 1-3.

PREPARATION OF SODIUM ZINCATE

Dissolve zinc chloride or sulphate in water, and raise nearly to boiling point. Add dilute ammonia (1:3) very gradually to the hot solution, to precipitate zinc hydroxide. Do not add excess of ammonia. Allow precipitate to settle, and decant off the liquid. Add more ammonia to the decanted liquid, and add any precipitate to the original precipitate. Wash the zinc hydroxide several times until it is free from chloride or sulphate. Filter under pump, to remove as much liquor as possible. Dissolve zinc hydroxide in hot 60° Tw. NaOH until the NaOH is saturated. Cool and filter through glass wool.

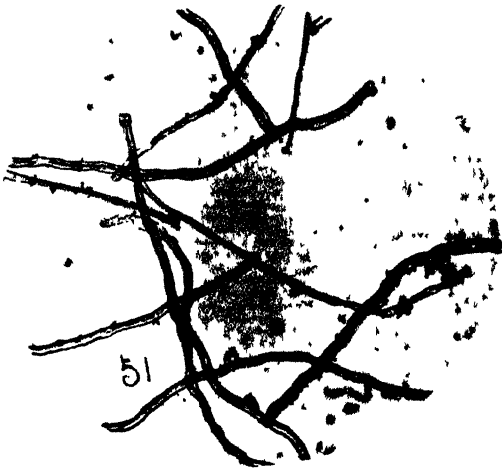


FIG. 1—Unsoured fibres.

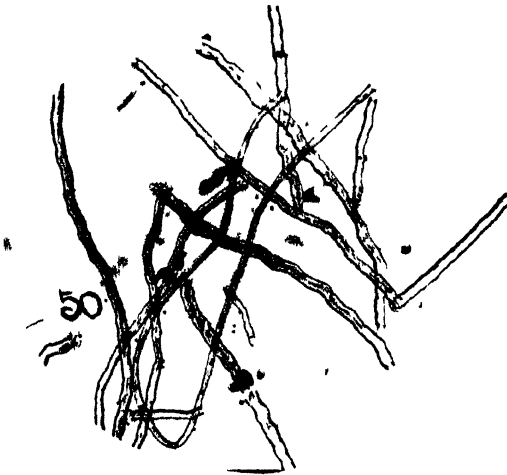


FIG. 2—Fibres fully
scoured and bleached.

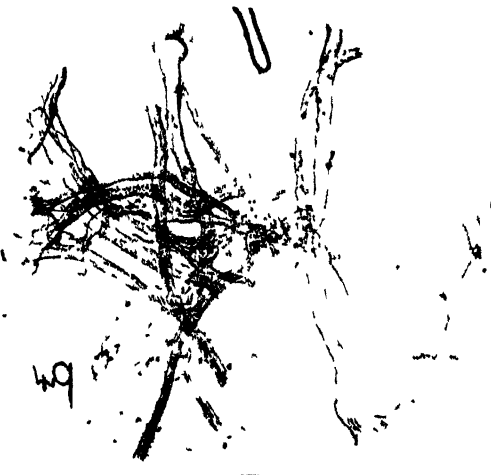


FIG. 3—Fibres
overbleached

15—INFLUENCE OF ASH CONSTITUENTS ON THE ELECTRICAL CONDUCTION OF COTTON

By A. C. WALKER and M. H. QUELL

It has been shown¹ that the electrical properties of textiles, such as cotton, silk, wool, and cellulose acetate silk, depend to a remarkable extent upon their moisture contents and chemical compositions. In addition, these properties have been considered to depend upon water-soluble, electrolytic impurities present in the fibres, since the insulation resistance of untreated* cotton has been improved very greatly by water washing.

Evidence will be presented in this paper to show that the improvement in d.-c. insulation resistance of cotton, secured by washing, is accompanied by a reduction in the inorganic ash content from about 1% of the dry cotton weight to a value generally less than 0.3 per cent.† Data will be given to show that the water-soluble salts present in raw cotton, which constitute about 70% of the ash weight, are principally potassium and sodium salts, and their removal by washing is accompanied by an improvement of between 50 and 100 fold in the insulation resistance. Since these salts are largely inorganic electrolytes, this improvement in resistance is termed *electrolytic*. A *total* improvement of between 150 and 200 fold can be secured if the washed cotton is dried under certain conditions. The difference between *electrolytic* and *total* improvement is due to changes in the moisture-adsorbing properties of the textile resulting from the manner of drying, and this difference, largely reversible by subsequent exposure of the cotton to high atmospheric humidities, is termed *transient* improvement. (The effect of atmospheric humidity on the insulation resistance of cotton is discussed in a subsequent paper (No. 17) which will appear in the April issue—*Editor*.)

The effects of ash constituents, other than Na and K on the insulating properties of cotton is small, and these effects are difficult to evaluate, since they are masked by the effect of atmospheric humidity.

In this investigation, primary consideration has been given to cotton since it is the most economical material available for use in telephone apparatus insulation, and the improvements in electrical properties secured by water-washing have led to its substitution for silk to a large extent in the telephone industry.

EXPERIMENTAL

Several years ago some experiments were made on the effect of salt electrolytes on the insulation resistance of commercially dyed cottons. The data are given in Table I.

These results indicated that the insulation resistance of raw cotton is lower than that of any of the dyed cottons; the resistance of the dyed cotton is increased as the quantity of salt added to the dye bath is decreased; the resistance is appreciably lower in the presence of even comparatively small

* Prior to these investigations on the electrical properties of cotton, a considerable quantity of cotton insulation used in telephone apparatus was undyed material, which received no treatment with water and therefore contained all of the naturally-occurring, inorganic salt impurities. Such untreated material is generally designated as "raw" cotton.

† See references given in an accompanying paper (No. 16) to similar results obtained by other investigators.

Table I
D.C. Insulation Resistance of Dyed Cottons

Colour	NaCl used in Dyebath in lb./100 lb. Cotton	Insulation Resistances*	
		As Received	After Washing†
Green	None ...	272 ...	269
Slate	None ...	76 ...	333
Orange	1.00 ...	16 ...	183
Yellow	1.00 ...	15 ...	392
Blue	1.75 ...	5.9 ...	248
Red	1.75 ...	5.7 ...	338
Brown	1.75 ...	4.5 ...	255
White (untreated) ...	None ...	2.6 ...	133

* These d.-c. insulation resistance measurements were made according to a direct deflection method previously described (¹), after equilibrating the textile with 75% relative humidity at 25° C. The resistances are expressed in kilomegohms per single thread of 30/2 cotton mounted between electrodes $\frac{1}{4}$ in. apart.

† These measurements were made after washing 2-gram samples of each cotton in 1 litre of boiling distilled water and oven-drying at 105° C.

amounts of salt than when the salt is substantially absent; also the contaminating salt can be removed by water washing, and when the cotton so washed is dried in an oven at 105° C., surprisingly large improvements are observed in the insulation resistance.

It will be shown that raw cotton contains about 0.3% K_2SO_4 and NaCl, principally the former, in addition to some other water-soluble salts. Washing with distilled or tap water suffices to remove practically all of these electrolytes. Calculations show that the amount of NaCl which could contaminate the dyed cottons in Table I is of the order of not more than 0.05% of the cotton weight, based on the contamination of the cotton with all of the salt present in the dyebath (1.75 lb. of salt/100 lb. of cotton). This contamination is very small compared with the natural salt content of raw cotton. Some salt is present probably even in the green and slate dye, since these dyes contain salt, whether in their dry states or in their concentrated solutions. The process used for the green dye differed from the others, involving an acetic acid bath, and the conditions were more favourable for the removal of traces of salt than in the other cases. Experiments have shown that dilute acetic acid solutions have no harmful effects upon the electrical properties of cotton, particularly if the cotton is oven-dried thereafter.

Since it is impracticable to use distilled water in the commercial purification of cotton, a study was made of several natural waters which might be used for this purpose. The results indicated that cotton washed in waters containing alkaline-earth salts, and but small amounts of alkaline salts, consistently gave higher resistances than those washed in distilled water, or waters containing appreciable amounts of the alkaline salts. This behaviour suggested that ionic interchange occurs between dissolved alkaline-earth salts in the wash water and some electrolytes present in the cotton, resulting in a reduction in the electrolytic content of the material. Consequently a systematic investigation was made to determine the ash constituents of cotton, both before and after washing in distilled water and various salt solutions; also to determine the effects of changes in the ash constituents on the insulation resistance of the material.

Preliminary tests indicated that washing 200 grams of cotton with 20 litres of distilled water gave reductions in total ash content and increases in insulation resistance comparing favourably with results obtained using greater volumes of water; also the washing temperature did not appear to influence critically the results.

Programme of Washing Experiments

A programme of experiments was conducted as follows—200-gram bundles* of raw cotton were first washed in 20 litres of distilled water. Separate bundles so washed were then washed with 10 litres of 0.0025 N† solutions of CaSO_4 , MgSO_4 , K_2SO_4 , Na_2SO_4 , or HCl . Each salt-washed bundle was finally washed in 10 litres of distilled water to remove any residual salts left in the cotton during the salt solution washings. All washings were with solutions at 40° C. The method of washing is described in a separate paper (No. 16).

Ash Analyses

Table II contains complete ash analyses of raw cotton and laboratory washed cottons treated with different amounts of distilled water or solutions as described in the foregoing programme. In addition, values are given for cottons washed in commercial equipment, using tap water to which definite amounts of Ca or Mg sulphate were added to counteract the effects of appreciable amounts of alkali-metal salts already present in the water. The values for the raw cotton are averages of seven complete analyses on this material; in the other cases the data are usually averages of two complete analyses.

The basic constituents are reported as elements, with the exception of Mg, Fe, and Al, which are reported as oxides,‡ the acidic constituents as acid radicals.

It is seen that washing with but 5 litres of water removes all of the phosphate and chlorine; reduces the potassium from 0.361% to 0.042%, the sodium from 0.03% to a negligible amount, the Mg from 0.07% (as oxide) to 0.034%, the SO_4 from 0.156 to 0.05%, while the SiO_2 , $\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3$ and Ca contents are practically unchanged. Increasing the volume of wash water reduces the potassium content to a negligible amount and decreases the SO_4 , SiO_2 , and $\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3$ somewhat. Since the principal reductions are in K, Na, SO_4 , Cl, and P, and as will be shown elsewhere,² these reductions are due to the removal of potassium as sulphate, phosphate, and as organic compounds, and the sodium as chloride, it seems reasonable to relate the improvement in insulation resistance to the decrease in Na+K content.

In Table III a comparison is given of the insulation resistances and Na+K contents of raw and washed cottons. The insulation resistances under (a) are initial averages on samples from each of the eight 25-gram skeins composing a bundle. These values were secured immediately after washing and oven-drying the bundles at 105° C. The (b) values are similar averages secured more than a year later. In most cases, at least four sets of measurements were made on each bundle during the year, and as will be seen from the (a) and (b) columns, marked decreases occurred in the resistances; the higher the initial value the greater appeared to be the decrease. Only the raw cotton appeared

* Representative bundles were prepared by first winding a large number of 25-gram skeins of cotton formed from a five-end yarn. This yarn was composed of threads wound from five spools of cotton in parallel. The skeins were numbered in order of formation from the spools, and the 200-gram bundles were prepared from a representative selection of eight skeins each. Separate samples of the raw cotton taken from the five spools before and after winding the skeins showed no significant variation in insulation resistance from spool to spool or from the outside to inside of the spools.

† This normality was chosen as being of the same order of magnitude as the Ca content in a natural water, which gave the best apparent improvement in commercial washing.

‡ The reasons for reporting the data as given are discussed in a separate paper (No. 16).

Table II
Cotton Ash Analysis

Bundle No.	Treatment	No. of Analysis	Ash Constituents—in percentage of the Dry Cotton Weight										Total	As Weighed
			K	Na	Ca	MgO	CO ₂	SO ₄	SiO ₂	FeO ₂ +Al ₂ O ₃				
7	Raw Cotton	...	0.361	0.030	0.054	0.070	0.200	0.156	0.037	0.048	...	1.046	...	1.049
(P ₂ O ₅ = 0.045%; Cl = 0.045%)														
Washed with Distilled Water.														
2	5 litres H ₂ O	2	0.042	<0.01	0.054	0.034	0.053	0.051	0.036	0.050	...	0.320†	...	0.320
6	10 "	2	0.025	<0.01	0.054	0.032	0.046	0.046	0.032	0.045	...	0.280†	...	0.285
8	20 "	2	0.016	0.001	0.058	0.038	0.050	0.038	0.033	0.046	...	0.279	...	0.280
10	37 "	1	0.002	0.008	0.061	0.046	0.054	0.038	0.019	0.036	...	0.264	...	0.275
40	40 "	1	0.002	0.004	0.061	0.036	0.064	0.038	0.021	0.023	...	0.257	...	0.266
13	40 "	1	0.002	0.001	0.054	0.027	0.042	0.038	0.019	0.019	...	0.202	...	0.200
80	80 "	2	0.005	0.003	0.059	0.038	0.049	0.038	0.019	0.029	...	0.240	...	0.235
Washed with Salt Solutions.														
1	K ₂ SO ₄ : 20-10-10*	1	0.031	0.007	0.049	0.022	0.042	0.034	0.018	0.017	...	0.220	...	0.226
9	Na ₂ SO ₄ : 20-10-10	2	0.004	0.008	0.046	0.030	0.040	0.019	0.016	0.018	...	0.181	...	0.200
5	MgSO ₄ : 20-10-10	2	0.004	0.002	0.024	0.073	0.020	0.018	0.020	0.017	...	0.178	...	0.184
3	CaSO ₄ : 20-10-10	2	0.002	0.001	0.082	0.022	0.080	0.042	0.022	0.021	...	0.271	...	0.271
15	"	1	0.006	0.003	0.085	0.014	0.082	0.038	0.028	0.028	...	0.284	...	0.272
E	CaSO ₄ : 20-30-10	1	0.004	0.001	0.081	0.002	0.090	0.028	0.019	0.024	...	0.249	...	0.254
B	CaSO ₄ : 30-10	2	0.002	0.001	0.064	0.002	0.093	0.047	0.026	0.032	...	0.302	...	0.296
A	CaSO ₄ : 40	2	0.003	0.004	0.093	0.011	0.092	0.045	0.030	0.035	...	0.313	...	0.314
C	CaSO ₄ : 40	2	0.004	0.001	0.086	0.010	0.085	0.035	0.034	0.023	...	0.278	...	0.276
Washed with HCl Solution.														
11	HCl: 20-10-10	2	0.004	0.002	0.007	0.002	none	0.004	0.018	0.009	...	0.046	...	0.047
Commercial Washings—Tap Water used treated with 5 lb. MSO ₄ /800 lb. of Cotton.														
K-1	CaSO ₄	2	0.007	0.001	0.091	0.002	0.112	0.011	0.019	0.032	...	0.276	...	0.282
K-3	MgSO ₄	3	0.007	0.003	0.081	0.053	0.059	0.089	0.020	0.036	...	0.348	...	0.346
Mixed Salt Solution—Laboratory Check on Commercial Test K-3.														
Solution used—0.005 N MgSO ₄ +0.0006 N K ₂ SO ₄ , Concentrations approximating those found in the Tap Water.														
F	Soln: 20-30	1	0.009	0.003	...	...	...	...	...	...	...	...	...	...

* The significance of the designation MSO₄: 20-10-10 is—Each number indicates the volume of liquid used, the bold figures being the volume of salt solution (MSO₄), and the light figures being the volumes of distilled water, in litres per 200 grams of cotton. The sequence of the numbers is order of washing.

† Na values are estimated in these totals since contamination occurred in the Na analysis. The actual analyses reported were 0.012%, and 0.016%, therefore it is probable that the true values were less than 0.010%.

Table III
Effect of Sodium and Potassium Ash Constituents on Insulation Resistance of Cotton Washed in Distilled Water
and in different Salt Solutions

Bundle No.	Treatment	Percentage Alkali Elements			Insulation Resistance at 75% Relative Humidity—25° C.		
		K	Na	Na + K	Initial (a)	One year later (b)	After 90/23* (c)
7	Raw cotton	0.361	0.03	0.391	2.6	2.6	1.6
2	5 litres H ₂ O	0.042	0.01	0.05	81	60	46
6	10 "	0.025	0.01	0.035	160	101	45
8	20 "	0.016	0.001	0.017	129	121	90
10	37 "	0.002	0.008	0.01	415	111	61
40	40 "	0.002	0.004	0.006	220	111	83
13	40 "	0.002	0.001	0.003	220	126	41
80	80 "	0.005	0.003	0.008	143	141	74
1	K ₂ SO ₄ : 20-10-10	0.031	0.007	0.038	83	80	70
9	Na ₂ SO ₄ : 20-10-10	0.004	0.008	0.012	84	64	41
5	MgSO ₄ : 20-10-10	0.004	0.002	0.006	275	142	100
3	CaSO ₄ : 20-10-10	0.002	0.001	0.003	215	141	98
15	CaSO ₄ : 20-10-10	0.006	0.003	0.009	210	68	60
E	CaSO ₄ : 20-80-10	0.004	0.001	0.005	354	126	68
B	CaSO ₄ : 80-10	0.002	0.001	0.003	294	143	75
A	CaSO ₄ : 40	0.003	0.004	0.007	229	176	59
C	CaSO ₄ : 40	0.004	0.001	0.005	470	134	124
11	HCl : 20-10-10	0.004	0.002	0.006	55	38	30
K-1	CaSO ₄ test	0.007	0.001	0.008	99	no values	—
K-1	MgSO ₄ test	0.007	0.003	0.010	207	no values	—
F	MgSO ₄ + K ₂ SO ₄ : 20-80	0.009	0.003	0.012	46	no values	—

* *Note*—The heading (After 90/23) indicates that the samples were equilibrated at 90% relative humidity at 23° C., for several days, then thoroughly dried with air at room temperature before measurement at 75% relative humidity—25° C.

to be unaffected. In one case (Test E) the set of samples was equilibrated continuously for 18 days. The average insulation resistance dropped from 354 kilomegohms to about 250 in two days, and then more gradually to a final value of 204 after the 18th day.

This behaviour of washed cotton, together with the fact that the separate skeins in each bundle differed as much as 100% in insulation resistance, despite the fact that this seemed unreasonable in view of the care taken in the washing procedure, suggested that the exposure of the washed cottons to varying cycles of atmospheric humidity might be responsible for the marked changes.

As a result of these observations, experimental work was undertaken to correlate the insulation resistance of cotton with moisture content through several humidity cycles of from dryness to saturation and return. The results of this work are recorded in a separate paper (No. 17). They show definitely that the initially high insulation resistance of washed, oven-dried cotton is not retained if the cotton is exposed to very high atmospheric humidities or to air saturated with water vapour. Consequently it was concluded that a more satisfactory comparison between the insulation resistances of washed cotton and the soluble ash constituents might be secured by preconditioning the textiles at some high humidity. Therefore, the results in Table III under (c) were obtained after conditioning all samples then available at 90% relative humidity at 23° C. for three days, followed by air-drying at room temperature an equal length of time.

CONCLUSIONS

Washing with but 5 litres of water causes an improvement in the insulation resistance of raw cotton of about 40 fold, based upon the (c) values in Table III. Improvements of between 50 and 100 fold are observed if greater volumes of water or Ca and Mg sulphate solutions are used. Even dilute solutions of K_2SO_4 , Na_2SO_4 , and HCl give improvements of between 30 and 70 fold. Improvements based on these (c) values, with raw cotton as 1.06 kilomegohms, represent as nearly as can be ascertained with the data available, the effects of removal of alkali salt electrolytes.*

Total improvements of 160 to 180 fold in the resistance of cotton are possible, e.g. tests 10 and C. These improvements are calculated on the basis of 2.6 kilomegohms for the untreated cotton. The difference between the total improvement and that characterised as *electrolytic* (50 to 100 fold), is termed *transient*, since this difference appears to be in the nature of a reversible effect dependent upon exposure of the purified cotton to high humidities and consequent changes which take place in the gel structure of the material due to swelling as moisture is absorbed.³

With increasing volume of wash water, the alkali salt content of cotton shows a progressive decrease, though it is evident from Table III that a relatively small amount of distilled water removes practically all of the harmful electrolytic salts, and is responsible for nearly all of the *electrolytic* improvement in resistance. The effort made to bring all of the different

*As discussed elsewhere (No. 16), about one-fourth of the K and all of the Na appear to be present in raw cotton in the form of K_2SO_4 and NaCl respectively. In addition, some K is present as phosphate and silicate. These water-soluble, strong electrolytes constitute about 40% of the total ash of raw cotton. The remaining K, found in the ash as K_2CO_3 , is presumably present in the cotton as readily-soluble organic compounds, and as such may contribute to electrolytic conduction, since they may ionise to some extent as weak electrolytes.

washed cottons to a comparable condition by equilibrating them at 90% relative humidity was not as effective as anticipated, and therefore the effect on insulation resistance of the removal of the last traces of alkali salt is masked by the much more pronounced effects of drying and atmospheric exposure. Although these results do not justify more quantitative discussion of the effects of electrolytic impurities and other factors, they have been most useful, not only in suggesting a more reasonable explanation of the behaviour of cotton after removal of electrolytic impurities, but also in improving inspection methods necessary in controlling the quality of washed textile insulation for telephone apparatus.

This transient effect explains some of the more important discrepancies in Table III. The fact that the insulation resistance of check tests* differed by as much as two fold in some cases, is considered to be due to the difficulty of uniformly drying the rather bulky bundles in the equipment available, and also to the possibility of exposure to high humidities soon after drying. This reasoning may apply also to those bundles of low Na+K content which did not change appreciably in insulation resistance during the year.

The resistance of the HCl-washed cotton is unexpectedly low, considering that the ash content is reduced to but one-fifth that of the other washed cottons, and the Na+K is negligible. Although it has been found that the strength of cotton yarn soaked in dilute HCl and dried at 105° C., is greatly reduced, this was not the case with the HCl-washed cotton followed by the distilled-water treatment, indicating that the final washing seemed to remove the acid effectively, a conclusion which could not be verified satisfactorily from the ash analyses, since any trace of the acid would have volatilised on ashing. It is significant that the acid washing did not alter the moisture adsorption of the cotton appreciably.† If acid hydrolysis had occurred it might be expected to cause a higher moisture content and, therefore, a lower insulation resistance. Therefore, it would appear that the unusual result in this case is due to some other cause, possibly the effect of the acid upon the gel structure of the cotton, perhaps in some manner changing the distribution of moisture and the mechanism by which current is conducted through the fibres.

The presence of 0.05% and 0.035% Na+K in the cotton from tests 2 and 6, Table II, may be responsible for the final (c) values of resistance being but 45 kilomegohms, as compared with higher values for washing with larger amounts of water, but this conclusion is of doubtful validity since tests 13 and 9 are lower in Na+K and have about the same final insulation resistances.

The initial values for the CaSO_4 and MgSO_4 solution washings are considerably higher than those of the other salt solution tests. Also, the 40-litre CaSO_4 solution washing (C) gave a higher resistance than the best of the water-washed cottons (test 10). These two exceptionally high values were not

* *E.g.* experiments 15 and C were checks on 3 and A respectively. In Table I the ash constituents of 3 and 15 check surprisingly well. Those of A and C do not check so well, but this is no doubt due to the fact that no washing with distilled water followed the salt solution washing, and one of these bundles may have been squeezed slightly drier of washing solution than the other, since both Ca and SO_4 are higher in one than the other.

† At 75% relative humidity, 25° C., the moisture content of this HCl-washed cotton was 8.07%. Two water-washed cotton samples, which gave insulation resistances of 108 and 73 kilomegohms, had moisture contents under these conditions of 8.00 and 8.12% respectively. The HCl-washed cotton had a resistance of 55 kilomegohms.

duplicated by other samples washed similarly. The difficulty of insuring uniform drying conditions is believed to be responsible for these results.

The average insulation resistance of CaSO_4 washed cotton, after preconditioning at 90% relative humidity, is 80 kilomegohms, based upon tests 3, 15, E, B, A, and C. For cottons washed in at least the same total volume of distilled water, the similar value is 65 kilomegohms. This difference is insufficient to warrant definite conclusions regarding the relative merits of the washing procedures used, in view of the effects of other factors previously discussed. However, definite benefit from the use of CaSO_4 or MgSO_4 has been secured commercially, as previously mentioned, and it is possible that the above difference between 80 and 65 is significant.

Verification of this possibility must await more quantitative information regarding the effects of atmospheric humidity and temperature upon the insulation resistance of purified cotton.

Ionic interchange does occur when cotton is washed in salt solutions, and though the results indicate that consistently lower Na+K contents were obtained with the alkaline-earth solutions, these differences also are insufficient to reveal any material effect upon insulation resistance. The principal ionic interchanges appear to take place between Ca and Mg, and a more detailed discussion of this effect is contained in a separate paper (No. 17), since it appears to have little direct bearing on the electrical properties of cotton.

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16—NATURALLY-OCCURRING ASH CONSTITUENTS OF COTTON

DISTRIBUTION OF ASH CONSTITUENTS AS SALTS AND CHANGES RESULTING FROM WASHING IN AQUEOUS SOLUTIONS

By A. C. WALKER and M. H. QUELL

Precise information on the inorganic ash constituents which are deposited in cotton fibres during growth, and on the changes which occur in these constituents when cotton is washed with distilled water or aqueous solutions, is desirable as an aid in understanding many of the properties of this important industrial fibre. In the previous paper (No. 15) reference was made to laboratory experiments in which raw (untreated) cotton was washed with distilled water and various aqueous solutions, and sufficient analytical data were given to show the effects of changes in the ash constituents upon the electrical properties of the cotton.

It is the purpose of this paper to present a discussion of the analytical data obtained in these experiments, together with a possible distribution of the ash constituents as salts occurring in the raw cotton. This distribution is based upon a somewhat unusual consideration of the analytical data. It will be shown that ionic interchange occurs when cotton is washed in aqueous salt solutions, the principal effect being the replacement of Mg^{++} in the cotton by Ca^{++} from $CaSO_4$ solutions used in washing, or the reverse if the solutions is $MgSO_4$. Although these analytical data were secured in an investigation of the electrical properties of cotton, they are the subject of a more general discussion in this paper, since it is possible that they may be of service in the study of other properties of cotton or other forms of cellulose.

EXPERIMENTAL

Table I gives ash analyses of 20 different washed cottons, and averaged analyses of seven separate determinations of the ash constituents of the raw cotton used in this work, together with analyses of two lots of commercially purified cotton and one partial analysis of cotton washed in a mixed salt solution, having concentrations of $MgSO_4$ and K_2SO_4 , approximately the same as found in the tap water used in one of the commercial washings.

The values given for the ash constituents of the washed cottons are generally averages of at least two analyses, although in some cases only one analysis was made. In these experiments great care was taken to provide as uniform a washing procedure as possible. This procedure, as well as the methods employed in making the analytical separations and determinations are described in an appendix to this paper.

As indicated in this appendix, 200-gram bundles, each composed of eight 25-gram skeins of cotton, were prepared for these washing experiments. Preliminary tests were made on separate bundles, washings being made with 5, 10, 20, and 37 litres of water at 40° C., also at 80° C., using 10 and 20 litres of distilled water. From an examination of the insulation resistance values obtained immediately after washing and drying these cottons at 105° C., and from the total ash contents of these cottons it was concluded that 20 litres of distilled water gave reductions in ash content of nearly the same amount as though more water was used; also, the washing temperature did not appear to influence the results critically. The insulation resistance values

Table I—Cotton Ash Analyses

Bundle No.	Treatment	No. of Analysis	Ash Constituents—in Percentage of the Dry Cotton Weight										Total	As Weighed
			K	Na	Ca	MgO	CO ₂	SO ₄	SiO ₂	FeO ₃ +Al ₂ O ₃				
7	Raw cotton	7	0.361	0.030	0.054	0.070	0.200	0.156	0.037	0.048	1.046	1.049		
(P ₂ O ₅ = 0.045%; Cl = 0.045%.)														
Distilled-Water Washings at 40° C.														
2	5 litres H ₂ O	2	0.042	0.011*	0.036	0.034	—	0.051	0.036	0.050	—	0.320		
6	10 "	2	0.025	0.012*	0.034	0.032	—	0.046	0.032	0.045	—	0.285		
8	20 "	2	0.015	0.001*	0.058	0.038	—	—	0.033	0.046	—	0.280		
12	20 "	2	0.013	0.005*	0.051	0.051	0.042	0.040	0.022	0.026	0.250	0.243		
37	37 "	10	0.002	0.008*	0.061	0.046	0.053	0.041	0.016	0.036	0.283	0.275		
40	40 "	1	0.002	0.004*	0.069	0.036	0.064	0.038	0.022	0.023	0.258	0.266		
13	40 "	1	0.002	0.001	0.040	0.207	0.032	0.030	0.016	0.019	0.135	0.200		
80	80 "	2	0.005	0.003	0.048	0.038	0.049	0.036	0.010	0.029	0.218	0.235		
Distilled-Water Washings at 80° C.														
14	10 litres H ₂ O	1	0.018	0.009	0.055	0.029	0.045	0.041	0.020	0.027	0.244	0.256		
4	20 "	1	—	0.002	0.059	0.040	0.063	0.029	0.018	0.026	0.237	0.243		
CaSO ₄ -Solution Washings at 40° C.														
3	CaSO ₄ : 20-10-10	2	0.0015	0.001	0.082	0.022	0.079	0.042	0.022	0.021	0.271	0.271		
15	CaSO ₄ : 20-10-10	1	0.006	0.003*	0.085	0.014	0.082	0.031	0.033	0.028	0.262	0.272		
E	CaSO ₄ : 20-10-10	1	0.0035	0.001	0.081	0.002	0.090	0.021	0.013	0.024	0.236	0.254		
B	CaSO ₄ : 30-10	2	0.0015	0.001	0.094	0.002	0.093	0.032	0.025	0.028	0.277	0.296		
A	CaSO ₄ : 40	2	0.003	0.004	0.091	0.011	0.092	0.044	0.029	0.035	0.309	0.314		
C	CaSO ₄ : 40	2	0.004	0.001	0.086	0.010	0.095	0.035	0.033	0.023	0.267	0.276		
MgSO ₄ -Solution Washings at 40° C.														
5	MgSO ₄ : 20-10-10	2	0.004	0.002	0.024	0.073	0.020	0.018	0.020	0.017	0.178	0.184		
Other Salt-Solution Washings at 40° C.														
1	K ₂ SO ₄ : 20-10-10	1	0.031	0.007*	0.049	0.022	0.042	0.034	0.018	0.017	0.220	0.226		
9	Na ₂ SO ₄ : 20-10-10	A	0.004	0.008	0.046	0.030	0.040	0.019	0.016	0.018	0.181	0.200		
"	"	B	0.004	0.007	0.045	0.030	0.007	0.019	0.014	0.019	0.145	0.177		
Note—9-A was ashed normally—below 350° C.; 9-B was ashed at red heat—lost CO ₂ .														
11	HCl: 20-10-10	2	0.004	0.002	0.007	0.002	0.000	0.004	0.018	0.009	0.046	0.047		
Commercial Washings—using Tap Water to which 5 lb. MSO ₄ was added/800 lb. Cotton.														
K-1	5 lb. CaSO ₄	2	0.007	0.001	0.091	0.002	0.112	0.011	0.019	0.032	0.276	0.282		
K-3	5 lb. MgSO ₄	3	0.007	0.003	0.081	0.053	0.059	0.089	0.020	0.036	0.348	0.346		
Combined Salt Washing—Distilled H ₂ O to which Mg and K were added in same proportions as found in the natural water used for K-1 and K-3.														
F	MgSO ₄ + K ₂ SO ₄ : 20-30-005N-0006N	1	0.009	0.003	—	—	—	—	—	—	—	—		

The eight analyses marked with (*) indicates that the Na values may be somewhat in error due to contamination during analysis. See page T133 for explanation of the designation (20-10-10).

of the cottons washed in 10 litres or more of distilled water were of approximately the same order of magnitude, with one exception. This exception, as discussed in the previous paper (No. 15), gave an unusually high value, not due to important changes in the ash constituents, but to the method of drying.

On the basis of these conclusions a programme of washing tests was carried out, in which 200-gram bundles were first washed with 20 litres of distilled water to remove most of the readily water-soluble salts and bring the samples to as nearly a uniform ash content as possible. Each bundle was then washed in 10 litres of a 0.0025 N aqueous solution, these being CaSO_4 , MgSO_4 , K_2SO_4 , Na_2SO_4 or HCl . Following these solution washings, each bundle was washed with 10 litres of distilled water to remove any residual salts. In several cases check washings were made; also several bundles were washed with CaSO_4 solutions only, or variations of the 20-10-10* programme above outlined. All washings were at 40° C., except the two at 80° C.

When the data, as originally reported, were tabulated according to the arrangement shown in Table I, the summations of the ash constituents for each sample were, in general, very close to the ash percentage as determined by weighing the ash before analysis, providing Mg, Fe, and Al were expressed as oxides and the remainder as elements or acid radicals.†

In Table I, the summation of the individual ash constituents checks very closely with the ash as initially weighed; in 12 of the analyses the differences between the summation and the gravimetric ash weight are less than 0.01% of the dry cotton weight; in six more they are less than 0.02%, in two others less than 0.04%, and only one, Bundle 13, shows a difference of as much as 0.065 per cent.‡

Bundles 2, 6, and 8 are not included in the above discussion of precision, since these bundles were analysed before the CO_2 determination was included in the procedure. Also SO_4 is missing in Bundle 8, for the same reason. These three bundles were used in developing the analytical procedure given in the appendix. Their analyses later assumed an importance not anticipated when the programme was outlined, and since several of the ash constituents were missing, and the Ca content appeared to be low in 2 and 6, an attempt was made to estimate the missing constituents and correct the others. A study of the data suggested a method by which this could be done with considerable accuracy. This method was useful also in correcting known or obvious errors in several of the analyses, and it was of particular importance in estimating the distribution of the ionic constituents of the ash as salts in the raw cotton. Further discussion of the data will be given after outlining this method.

* In the tables, the different samples are designated—M SO_4 :20-10-10. Each number indicates the volume of liquid used, the bold figure value being volume of salt solution (M SO_4 or HCl), those not in bold figures being volumes of distilled water in litres per 200 grams of cotton. The sequence is order of washing.

† Higgins⁸ concluded from certain benzene extractions of cotton that some of the fatty acid is present as a magnesium salt; Schunk⁸ treated cotton with Na_2CO_3 , and concluded from subsequent treatments that Fe and Al are present in organic combination. Organic salts of these metals become oxides on ignition at 350° C., the temperature used in these experiments.

‡ The analyses for Bundle 13 are in error, save for the Na and K values, due to accidental spilling of part of the solution after taking aliquot samples for the Na and K determinations. They are included to provide a check on Na and K for washings in 40 litres of water. Bundles 10 and 40 have Na values which are too high due to a small though indeterminate contamination with Na during one of the analytical separations, before the method of aliquoting was adopted.

Table II—Cotton Ash Analyses

Bundle No.	Treatment	Ash Constituents—Milliequivalents/100 gr. Dry Cotton										Ratio* base/acid 1-00
		K+	Na+	Ca++	Mg++	CO= 6.68	SO= 3.26	SiO= 0.97	P.O= 1.05	Cl-		
7	Raw cotton	9.25	1.29	2.70	3.48	...	...	...	...	1.27	...
2	5 litres H ₂ O	1.08	0.49	1.80	1.69	...	1.09	0.94	...	...	...
6	10 "	0.64	0.52	1.72	1.59	...	0.96	0.84	...	...	...
8	20 "	0.40	0.03	2.92	1.90	...	—	0.87	...	...	...
12	20 "	0.34	0.23	2.57	2.54	...	1.41	0.57	...	...	1-035
10	37 "	0.06	0.33	3.04	2.28	...	1.77	0.43	...	...	1-01
40	40 "	0.04	0.16	3.43	1.79	...	2.14	0.79	...	...	0.99
13	40 "	0.06	0.06	2.00	1.34	...	0.82	0.63	...	0.017	...	
80	80 "	0.13	0.13	2.39	2.18	...	1.64	0.27	...	0.011	1-04	
14	10 litres H ₂ O	0.47	0.40	2.75	1.44	...	0.86	0.53	...	...	1-11
4	20 "	—	0.10	2.96	1.98	...	0.61	0.47	...	...	0.965†
3	CaSO ₄ : 20-10-10	0.04	0.06	4.08	1.09	...	0.88	0.57	...	...	1-01
15	CaSO ₄ : 20-10-10	0.15	0.13	4.25	0.70	...	0.73	0.87	...	...	1-065
E	CaSO ₄ : 20-30-10	0.09	0.06	4.04	0.10	...	3.00	0.33	...	...	1-11
B	CaSO ₄ : 30-10	0.04	0.06	4.69	0.10	...	3.09	0.67	...	...	1-08
A	CaSO ₄ : 40	0.08	0.16	4.53	0.55	...	3.05	0.92	...	...	1-01
C	CaSO ₄ : 40	0.11	0.06	4.32	0.50	...	2.50	0.87	...	...	1-095
5	MgSO ₄ : 20-10-10	0.11	0.10	1.18	3.62	...	0.68	0.53	...	...	0.875
1	K ₂ SO ₄ : 20-10-10	0.79	0.32	2.43	0.70	...	1.41	0.47	...	...	1-240
9 *	Na ₂ SO ₄ : 20-10-10 A B	0.09 0.11	0.35 0.32	2.29 2.25	1.48 1.49	...	1.32 0.23	0.40 0.40	...	...	1-270
11	HCl: 20-10-10	0.11	0.10	0.36	0.10	...	none	0.47	...	...	—
K-1	CaSO ₄	0.17	0.06	4.54	0.10	...	3.72	0.50	...	...	1-07
K-3	MgSO ₄	0.17	0.13	4.04	2.62	...	1.95	0.53	...	...	1-00

* In calculating this ratio, Na is omitted in the washed cottons, since errors vitiate this value in some cases—in all others it is substantially negligible; Mg is omitted also since it is assumed present as organic salt; the Fe and Al are omitted for the same reason.

† K omitted, since it was not determined.

The method involves the following considerations—

If the data are tabulated in terms of milliequivalents (m.eq.) of the separate ionic constituents per 100 grams of cotton (Table II), it is seen that the ratio of base/acid equivalents is surprisingly close to unity for the raw cotton, if only the constituents K, Na, Ca, CO_3 , SO_4 , SiO_3 , P_2O_7 , and Cl are used. These ratios for the different purified cottons are nearly unity in most cases if only K, Ca, CO_3 , SO_4 , and SiO_3 are considered. Mg, Fe, and Al are omitted, since the assumption on page 1133 indicates that they should be reported as oxides, also the base/acid ratios are more nearly unity without them.

Further, it seems reasonable to assume that Na and Cl exist in raw cotton as NaCl, since these ions are present in nearly equivalent quantities and both are practically absent in all of the washed cottons.*

Phosphorus is assumed to be in a readily soluble inorganic salt form, since it is required in the base/acid ratio for raw cotton, but not in that for the washed cottons.† The logical water-soluble salt form for the phosphorus is K_2HPO_4 , which becomes $\text{K}_4\text{P}_2\text{O}_7$ on ignition.‡

The silicate content of raw cotton is reduced from 0.97 m.eq., in raw cotton to about 0.50 m.eq., after washing with at least 20 litres of distilled water. This suggests that part of the silicate is water-soluble, possibly being associated with potassium in the raw cotton, while the insoluble remainder may be CaSiO_3 . Similarly the SO_4 content is reduced from 3.26 to a nearly constant value of 0.8 m.eq. It seems reasonable to assume that this residue is present as comparatively insoluble CaSO_4 . In raw cotton, and in those washed samples in which SO_4 is appreciably in excess of 0.80 m.eq., the excess is assumed to be present as K_2SO_4 , since K is the only element reduced by washing to as great a degree as the acid radical SO_4 . All Ca and K in excess of the amounts associated with SO_4 and SiO_3 are assumed to be present in the cotton, both raw and purified, as organic salts which become carbonates on ignition at 350° C. On this basis the total CO_3 values of the different samples balance most effectively.

An outstanding feature of the data, thus corrected, is that the discrepancies between ash as weighed and as summed up from the individual analyses are less than 0.01% of the cotton weight in all but four cases.‡ Table II shows the distribution of the ash constituents as salts based upon this method of computation.

* The sensitive silver nitrate test for Cl revealed no more than a trace of Cl in several of the washed cotton ash solutions. Also the Na content was in no case more than 0.01% in the washed cotton ash, and thus the omission of the Na in the ratio of base/acid introduces but a slight error. It is possible that a small amount of Na may be present in the ash of washed cotton, although all of the Na may be in the form of NaCl in the raw material. This may be the result of loss of Cl originally associated with Na, as volatile NH_4Cl through combination with the nitrogen present in cotton (0.1 to 0.2% N, according to Fargher and Withers).⁴ A loss due to such interchange is discussed by Roberts⁵ in studies of tobacco ash.

† Calvert⁶ found that nearly all of the phosphorous in cotton could be removed by cold water extraction. His values (0.028–0.055% P_2O_5) and Lester's value (0.056%)⁷ for raw cottons are of the same order as the value reported in Table I.

‡ The SO_4 content of Bundle 8 was assumed to be equivalent to the CaSO_4 content of raw cotton in milliequivalents (0.80 m.eq.). CO_3 was then estimated from the difference between total Ca and the portions assumed to be associated with SO_4 and SiO_3 , plus the CO_3 combined with the excess of K over that associated with K_2SiO_3 . Ca values in Bundles 2 and 6 seemed to be low in comparison with 8 and other water-washed cottons. These were corrected to the value for raw cotton (2.70 m.eq.) and the missing CO_3 values for these bundles computed as in the case of Bundle 8.

The base/acid ratios for Bundles 1 and 9 deviated from unity more than the others, and they were the most difficult to correct according to the method used in preparing Table III. The potassium content of Bundle 1 appeared to be higher than could be accounted for on the assumed basis, consequently the distribution of Ca as SiO_3 , SO_4 , and CO_3 was made first, and the remaining K over that associated with the residual CO_3 was assumed to be present as SO_4 , necessitating an assumption that the SO_4 value for this bundle was too low.*

A similar attempt to evaluate the data for Bundle 9 was troublesome, particularly since the two check analyses of this bundle were made with unusual care. The separate ion-constituents, except CO_3 ,† check surprisingly well, but the totals are not in good agreement with the ash as initially weighed. On comparing these analyses with that of Bundle 1, the SO_4 values appear to be low. Consequently the procedure described for Bundle 1 was adopted in supplying correct values for the ash constituents as salts, with the exception that the Na values were assumed to be correct, and the discrepancy in SO_4 content was corrected to correspond with the Na content. On this basis the totals check much better with the ash as weighed.

Other possible explanations for the few discrepancies between ash summations and ash weights remaining after applying the above-discussed corrections are that in these cases the ashing of the cotton may have been somewhat incomplete, therefore giving too high an ash weight, or that the total ash may have absorbed a small amount of moisture from the air during weighing.

The principal facts revealed by an examination of the data as presented in Table III are as follows—The ash of cotton prior to any water treatment is very close to 1%,‡ and water washing reduces it to a value between 0.2% and 0.3 per cent. This reduction is not surprising, since it is found that over 0.4% of the raw cotton ash exists as K_2SO_4 , K_2SiO_3 , $\text{K}_4\text{P}_2\text{O}_7$, and NaCl , while the remaining potassium (0.364% as K_2CO_3) results from the ignition of organic potassium compounds, and it seems reasonable to assume these to be water soluble, since washing with more than 20 litres of water removes practically all of the potassium salts. Washing also halves the Mg content, but leaves the Ca, Fe, and Al contents almost unchanged.

The potassium content of purified cotton appears to depend upon the concentration of potassium in the water used in washing.§ The amounts of potassium present in any of the bundles washed with at least 40 litres of solution are almost negligible. The presence of MgSO_4 in water also containing K_2SO_4 appears to have little effect upon the retention of potassium by the cotton, since the water used for Bundle 1 contained no MgSO_4 , while that

* This does not seem inconsistent, since the SO_4 determinations are considered to be the least accurate in this work.

† One of these determinations was ashed at the customary temperature of 350° C., the other at a bright red heat where the CaCO_3 was converted to CaO , thus accounting for the difference in the CO_3 content between these two determinations.

‡ According to Matthews⁹ the ash of cotton never exceeds 1%. Lester⁷ found that 0.61% of cotton ash could be removed by water extraction from a cotton having an ash content of 0.82%. Other investigators have reported similar results.¹⁰

§ The same amount of K_2SO_4 was added to the water used to wash Bundle F as that reported in the analysis of the water used in the commercial washings K-1 and K-3, and the potassium contents of the cotton in all three of these washings are much the same. Further, Bundle 1 was washed in a K_2SO_4 solution of 0.0025 N, while the concentration of K_2SO_4 in the water used for Bundle F was 0.0006 N. This ratio 0.0025/0.0006 is surprisingly close to the ratio of K in the ash of these two cottons.

used for Bundle F contained this alkaline-earth salt in addition to the K_2SO_4 . The marked effects of $CaSO_4$ or $MgSO_4$ in the wash water, on the Ca or Mg content of the cotton clearly indicate that ionic interchange does take place between Ca^{++} and Mg^{++} , but no clear evidence is found to show that alkaline-earth salts in the wash water aid materially in reducing the alkali metal content of the cotton by ionic interchange, as might be expected from the results of other investigators.*

Table IV

Ionic Interchange illustrated by a Comparison of the Ash Constituents of Cotton Washed in Water and in Aqueous $CaSO_4$ Solutions

Washing Conditions	Ionic Ash Constituents in milliequivalents per 100 grams of Dry Cotton					
	K^+	Ca^{++}	Mg^{++}	CO_3^{--}	SO_4^{--}	SiO_3^{--}
20 litres of Dist. H_2O ...	0.37	2.70	2.22	1.53	0.80	0.72
(Avg. Bundles 8 and 12)						
$CaSO_4$: 20-10-10 ...	0.10	4.17	0.90	2.78	0.84	0.65
(Avg. Bundles 3 and 15)						
Net change ...	- 0.27	+ 1.47	- 1.32	+ 1.25	+ 0.05	- 0.07

Table IV gives a comparison of the principal changes which occur in the ion-constituents of K, Ca, Mg, CO_3 , SO_4 , and SiO_3 when cotton is washed in 20 litres of distilled water and when it is washed in this same amount of water followed by 10 litres of $CaSO_4$ solution and 10 litres of distilled water.

The decrease in Mg content is nearly equivalent to the increase in Ca and CO_3 contents. The magnitudes of these changes are much greater than any possible errors in the individual values, while at the same time the changes in all of the other ionic constituents are negligible by comparison. Therefore, it is reasonable to conclude that most of the gain in Ca is by ionic interchange with Mg in some organic magnesium salt. The small change in SO_4 emphasised the fact that the washing of cotton in sulphate solutions is not necessarily accompanied by appreciable contamination of the cotton with sulphate, provided the excess sulphate solution is removed by a final water washing. The ionic interchanges resulting from the other salt washings have been computed in a similar manner. The net changes are summarised in Table V.

Table V

Changes in the Ash Constituents of Cotton Resulting from Washing in Water as Compared with Aqueous Salt Solutions

Salt Washing	Net Change in Ionic Ash Constituents in milliequivalents per 100 grams of Dry Cotton						
	Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^{--}	SO_4^{--}	SiO_3^{--}
$MgSO_4$...	- 0.03	- 0.21	- 1.52	+ 1.40	- 0.85	- 0.42	- 0.22
K_2SO_4 ...	+ 0.19	+ 0.47	- 0.27	- 1.52	- 0.12	- 0.09	- 0.25
Na_2SO_4 ...	+ 0.22	- 0.22	- 0.41	- 0.74	- 0.22	- 0.40	- 0.32

Discussion of Ionic Interchange as shown in Table V

There is a loss of 1.52 m.eq. in Ca and a gain of 1.40 m.eq. in Mg, resulting from the $MgSO_4$ washing, this being just the reverse of the effect produced by $CaSO_4$ -solution washing. It is interesting to note that the loss of CO_3 is much less than the loss of Ca. The losses in SO_4 and SiO_3 are greater than the

* Stiles¹¹ showed that in the adsorption of NaCl by carrot tissues, the excess Na^+ absorbed was replaced by Ca^{++} , K^+ , and Mg^{++} in the solution. Similar replacements were found by Redfern¹², Stoklasa¹³, and by Petrie.¹⁴ Edge¹⁵ found salt replacement in cellulose, while P. Rona and L. Michaelis ascribed marked adsorption of electrolytes (dyes) by cellulose to its mineral content, even in ash-free filter paper.¹⁶

changes in these ions in the CaSO_4 washings, suggesting that Mg replaces Ca in both organic and inorganic salts. The gain in Mg is less than the loss in Ca due perhaps to the loss of soluble MgSO_4 formed by interchange of Mg with Ca in CaSO_4 , which appears to be quite insoluble when present in cotton.

The changes observed in the ash constituents due to washing in K_2SO_4 and Na_2SO_4 solutions are more difficult to interpret, and no doubt more work should be done to evaluate accurately these effects. However, one fact to be noted is that all of the changes in these alkali-salt washings are negative, except the changes in the metal ions which are present in the wash water. This suggests that whatever replacement occurs in washing is followed by solution of the greater part of the soluble alkali formed. The decrease in the ash content resulting from washing with HCl appears to be due to a displacement of the acid ions in the cotton by Cl⁻, and subsequent solution of the chlorides thus formed. The residual ash consists mainly of calcium silicate with traces of Na and K silicates and calcium sulphate. The residual Mg, Fe, and Al are assumed, for simplicity, to be in organic combination. However, the actual distribution of these elements can have but little effect upon conclusions which may be derived from the assumed arrangement, since the quantities involved are small. It is not surprising that HCl and HF treatments are required in the preparation of ash-free filter paper, or that cotton can be rendered practically ash-free by proper bleaching and acid treatments, followed by careful washing with very pure, ash-free, distilled water. The unexpected feature of the acid-washing experiment is the low resistance of the cotton (I) notwithstanding its low ash content. This may be due to partial hydrolysis of the surfaces of the cotton fibres by contact with the acid as discussed in the previous paper.

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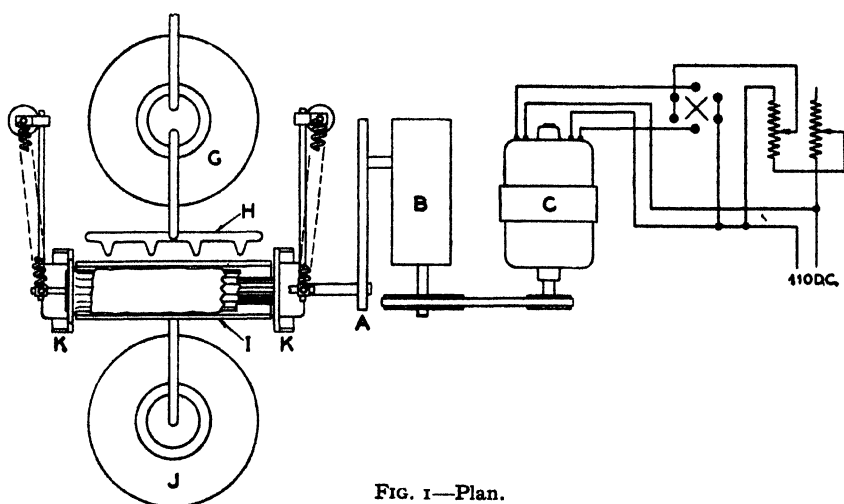


FIG. 1—Plan.

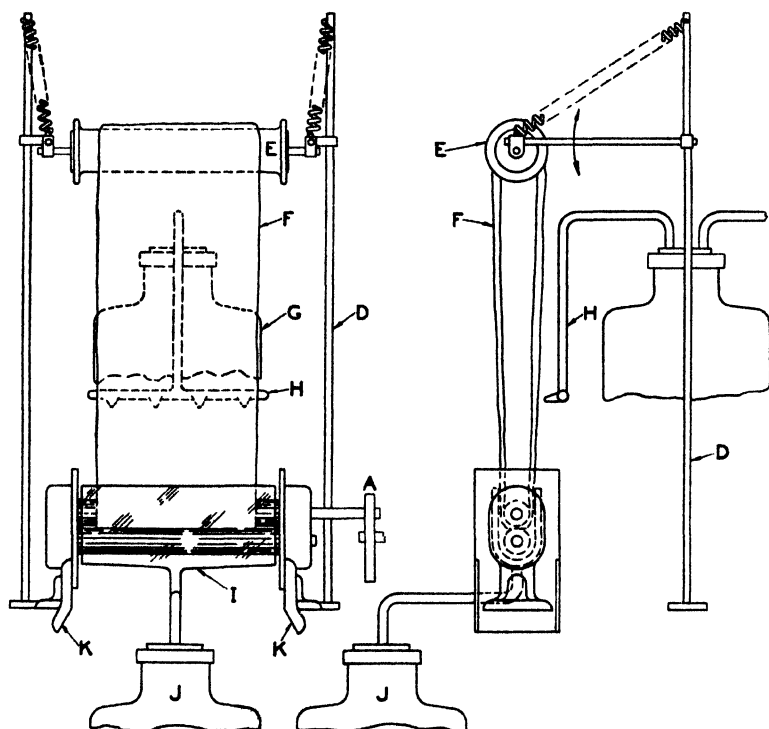


FIG. 1—Elevation.

APPENDIX

Method of Washing Cotton

Preparation of Bundles of Cotton for Washing—Uniform bundles of cotton of 200 grams each were prepared by first winding a large number of 25-gram skeins of cotton from a five-end yarn. This yarn was composed of

threads taken from five spools of cotton; thus one-fifth of each 25-gram skein was contributed by each spool. The skeins were numbered in order of formation from the spools, and the 200-gram bundles were prepared from a systematic selection of skeins so that both outside and inside of each spool would be represented in each bundle. Separate samples of cotton were taken from the five spools both before and after winding the skeins. Insulation resistance measurements and chemical analyses of these separate samples showed no significant variation from spool to spool or from the outside to inside of the spools.

It was found that the eight skeins composing each bundle could not be washed in the apparatus developed without tangling and breaking of threads. To overcome this difficulty each bundle was protected by enclosing it in a flat endless plain gauze bandage.

Apparatus for Washing Cotton—A simple, all-metal frame laundry wringer was set up as shown in Fig. 1. The wringer handle was replaced with a sprocket (A), driven by chain through a reducing gear mechanism (B), and variable speed motor (C). The motor was equipped with a reversing switch so that the rolls could be reversed in direction of rotation. Special rolls, made from rubber of low sulphur content were used, and these were washed for hours prior to use, with a clean bundle of cotton and distilled water to prevent contamination. Uprights (D) were placed in such a position that they supported a pyrex glass roller (E) about 12 in. above the upper wringer roll. This roller was supported on cantilever arms with spring tension so that it was free to move up or down to take care of shrinkage in the diameter of the bundle (F) during washing, and yet maintain the bundle under moderate tension. A 20-litre glass carboy (G) equipped with a spray manifold (H) having four calibrated tips of equal volume of discharge, supplied a continuous stream of wash water upon the band of cotton as it passed through the "bite" of the wringer. Air pressure applied to the water surface in the carboy maintained the continuous flow of water. On reversal of direction of wringer rotation, the water sprayed upon the cotton remained in contact with it, while the bundle travelled up over the idler roller (E) and down to the "bite" of the rolls on the other side, thus giving a somewhat longer time of contact of the water with the cotton.

Below the wringer roll, a special glass gutter (I) was mounted, in which the wash water drained to a large pyrex jar or carboy (J). Grit from the gears was excluded from the wringer rolls and glass gutter by close-fitting hard rubber panels (K) mounted at the end of the rolls. A blank test without a bundle showed that the amount of contamination caused by the flow of 20 litres of water through the system was negligible. Twenty litres of commercial grade distilled water gave 0.0439 gram residue on evaporation.* In the blank test this was increased to 0.0520 gram. Thus these residues corresponded to 0.022% and 0.026% of the weight of 200 grams of cotton, a gain of but 0.004 per cent.

* This relatively high residue in the commercial grade of distilled water, as well as the observation that occasional bottles contain visible residue, caused us to set up a separate still to prepare freshly distilled water for the washing of cotton, since the regular laboratory supply was inadequate for the washing of so many bundles. However, bundles 2, 6, 8, 10, and 40 were washed with the commercial water. Leaching of calcium from the glass by this commercial water may explain the fact that the Ca-content of the ash from bundles 10 and 40 was slightly higher than that of the raw cotton. It was not considered necessary to repeat the blank experiment on the wringer since the amount dissolved by the 20 litres of water in the above test was obviously very small.

It was planned to evaporate all of the wash water obtained in these tests, and analyse the residues to complete the balance of ash analyses of cotton. The accuracy of the cotton ash determinations made it unnecessary to carry out this part of the programme, particularly since the time available for this investigation could not be extended to include this additional work.

It was found that during the washing the bundle gradually decreased in length, due to the action of the rolls in causing a sort of loose kinking in the cotton threads within the bundle. Simply reversing the direction of rotation of the rolls caused immediate lengthening of the bundle, the reversal apparently serving to straighten out these kinks. Rotation in one direction could be continued for about 15 minutes before the reduction in length of the bundle became excessive. Reversals every five to ten minutes sufficed to keep the bundle in satisfactory condition, and washing has been continued for a whole day with no visible effect upon the cotton.

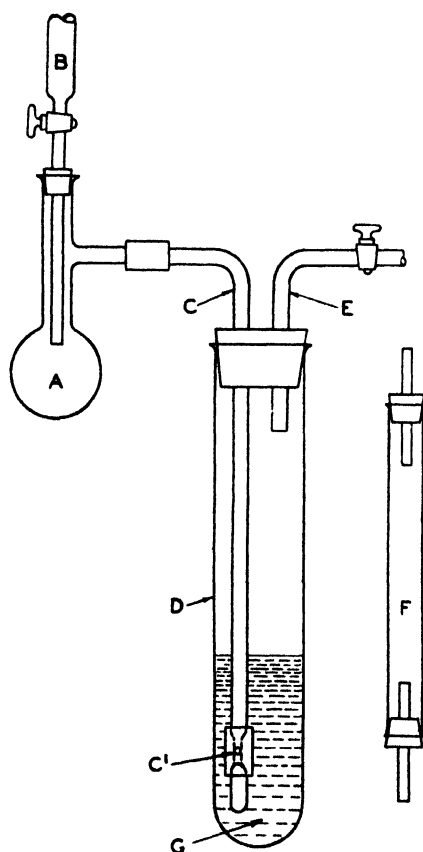


FIG. 2

Methods of Separation and Analysis of Cotton Ash

Preparation of Cotton for Analysis—Fifty-gram samples of cotton were formed into compact cylinders about 2 in. high by $1\frac{1}{4}$ in. in diameter, using a hydraulic press and a pressure of about 60-80 tons/sq. in., a procedure similar to that described by Williams.¹⁷

Drying—These cylinders were dried overnight at 105–110° C., to determine the moisture-free weight.

Ashing—Total ash was determined by igniting single cylinders of cotton in a covered platinum dish, using an electric muffle furnace, until the cotton was completely charred and the ashing then continued with the cover removed, until free from carbon. The temperature did not exceed 350° C., and the ashing usually required from four to six hours.

Determination of CO_2 —The CO_2 -content of the ash was determined by means of a special apparatus shown in Fig. 2. The weighed ash was transferred to a 50 c.c. distilling flask (A) and 10 c.c. of approximately 4-N HCl placed in the funnel (B). The side-arm of A made a glass-to-glass connection to the glass tube (C), through heavy rubber tubing. The lower end of C was fitted with a Bunsen valve (C'), and C was inserted through one hole of a two-hole rubber stopper closing the mouth of the large pyrex test tube (D), which was about 13 in. long by 1 in. in diameter. The rubber stopper also contained an outlet tube fitted with a stop-cock (E).

This apparatus was first evacuated several times, after the ash was placed in A, by applying vacuum at E, with the stop-cock on funnel B closed. It was brought to atmospheric pressure after each preliminary evacuation with CO_2 -free air from the soda-lime tube (F), connected to E. About 25 c.c. of a 0.2 N $\text{Ba}(\text{OH})_2$ solution (G) was added to D and the system again evacuated. Stop-cock E was closed and the HCl from B slowly added to A. A few drops of acid were left in B to avoid the possibility of air entering A during the analysis. The acid solution of the ash was boiled gently with a small flame held under A until steam could be heard condensing in the cold $\text{Ba}(\text{OH})_2$ solution, indicating complete displacement of CO_2 by steam in A. CO_2 -free air was then admitted through E to bring the test tube to atmospheric pressure, the distilling flask was disconnected and all the CO_2 in D absorbed by shaking the test tube. The stopper was removed and the solution washed to the bottom of D with hot, distilled water. The excess $\text{Ba}(\text{OH})_2$ solution was titrated with 0.1 N HCl, using phenolphthalein as indicator. The titration was carried out slowly, with frequent shaking, to prevent loss of CO_2 from interaction of the acid with the precipitated BaCO_3 .*

Determination of SiO_2 —The acid solution of the ash was transferred to a platinum dish and dehydrated three times with HCl, filtering each time, and finally washing with hot water. The precipitate of SiO_2 was ignited and treated with HF three times to remove SiO_2 , a few drops of H_2SO_4 being added after the first treatment. The small residue of Fe_2O_3 and Al_2O_3 remaining after this treatment was added to the amount of these oxides determined later in the procedure.†

Separation and Determination of SO_4 —The acid filtrate from the SiO_2 separation was evaporated to about 10 c.c. BaCl_2 solution was added, with constant stirring to precipitate BaSO_4 , in as uncontaminated a state as possible. The conditions of precipitation were those recommended by Johnston

* The following blanks are given to illustrate the accuracy of the method, using Na_2CO_3 prepared from the bicarbonate in accordance with the procedure of Talbot.¹⁸

Weight of Na_2CO_3 taken (1)	0.1994 gram.	Found	0.200 gram.
(2)	0.2132 "	"	0.2130 "
(3)	0.2343 "	"	0.2340 "

Average deviation = 0.0004 gram.

† Fe and Al are likely to be precipitated as basic salts in the pores of the filter paper during filtration if the washing with acidified water has been stopped before all traces of the soluble Fe and Al salts are removed.¹⁹

and Adams.²⁰ The filtrate was then treated with this procedure reversed to remove excess Ba.

Separation of Fe, Al, and P from Ca, Mg, Na, and K—The filtrate from the sulphate determination of raw cotton ash contained P in excess of the Fe content. Consequently sufficient standard Fe solution was added to take care of the P in the precipitation of Fe, Al, and P from the other salts. In washed cotton ash, numerous tests proved the absence of all but a trace of phosphate, rendering the addition of more Fe unnecessary. After adding the standard Fe solution, the solution was oxidised with a few drops of H_2O_2 to convert all Fe to the ferric state, and Fe, Al, and P were precipitated by neutralising carefully with NH_4OH , using methyl red as indicator.²¹ The precipitate was ignited and weighed as $\text{P}_2\text{O}_5 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$. To separate, this residue was fused with a mixture of anhydrous Na_2CO_3 and pure silica, cooled and extracted with water and filtered. The P_2O_5 was determined in the filtrate as $\text{Mg}_3\text{P}_2\text{O}_7$, and the Fe and Al by difference. Where excess iron was added the results were corrected for this additional amount, and in the absence of P, the fusion was omitted and Fe and Al ignited as oxides directly after filtration.*

Separation of Ca and Mg from Na and K—The filtrate from the Fe, Al, and P separation was evaporated to dryness in a platinum dish and the excess NH_4Cl fumed off. The residue was dissolved in 1 c.c. of concentrated HCl and washed into a 100 c.c. beaker, keeping the total volume to 15 c.c. Ca and Mg were precipitated as carbonates from this solution by adding 15 c.c. of 95% ethyl alcohol and 25 c.c. of 50% alcoholic ammonium carbonate reagent.²² The combined carbonates were filtered off on a fritted-glass crucible (Schott-Jena 1-G/4) after standing overnight to permit the MgCO_3 to crystallise. The washed precipitate of mixed carbonates of Ca and Mg were dissolved in 5% HCl and the Ca precipitated as oxalate, filtered, dissolved in hot 5% H_2SO_4 and titrated with N/20 KMnO_4 . Mg was precipitated from the filtrate overnight as NH_4MgPO_4 , ignited and weighed as the pyrophosphate.

Separation and Analysis for Na and K—The filtrate from the Mg precipitation was acidified with HCl and evaporated to dryness in a platinum dish and the excess NH_4Cl fumed off. This residue of Na and K was dissolved in a few drops of HCl and transferred to a 100 c.c. volumetric flask and made up to volume. Fifty c.c. portions of this were used for the Na and K determinations.

Sodium—Na was determined by evaporating the 50 c.c. aliquot to 1 c.c. and precipitating the Na in the form of uranyl zinc sodium acetate, by the method of Barber and Kolthoff.²³ The method of Caley and Foulk²⁴ precipitating uranyl magnesium sodium acetate was used for raw cotton, since it was preferable for larger quantities of Na.

Potassium—Potassium was determined by precipitation as K_2PtCl_6 from an alcoholic solution.²⁵ Traces of SO_4 were first removed by precipitation as BaSO_4 to prevent contamination of the chloroplatinate precipitate with insoluble sulphate of sodium.

Determination of Chlorine—Chlorine was determined on a separate sample of the ash dissolved in HNO_3 , and precipitated as AgCl . Tests were made on a number of the washed cottons, but no more than a trace was found in those tested.²⁶

* It is important to note that this separation was first practised using milk of CdCO_3 as precipitant. This method was abandoned after part of the analyses had been completed, since it was found that the supply of CdCO_3 was contaminated with Na. In Table II those analyses in which contamination occurred are marked with *.

THE JOURNAL OF THE TEXTILE INSTITUTE TRANSACTIONS

17—EFFECT OF ATMOSPHERIC HUMIDITY AND TEMPERATURE ON THE RELATION BETWEEN MOISTURE CONTENT AND ELECTRICAL CONDUCTIVITY OF COTTON

By ALBERT C. WALKER

The data to be given in this paper show the effect of successive equilibrium humidity cycles on the relation between (*a*) relative humidity and moisture content; (*b*) insulation resistance and relative humidity; and (*c*) insulation resistance and moisture content, for raw and water-boiled cotton at constant temperature (25° C.). These data have been of considerable assistance in explaining the behaviour of cotton, particularly the fact that its d.-c. insulation resistance, when measured at some definite test condition,* is dependent, to a surprising extent, upon previous treatment, *e.g.* the manner in which wet cotton is dried, temperature of drying, and the atmospheric conditions to which it is exposed after drying, before being measured under the comparable test conditions.

The information secured as a result of this investigation has been valuable in improving the practical methods of inspection used to control the quality of textiles for electrical insulation in telephone apparatus.

Previously it was shown¹ that the relation between the insulation resistance (I.R.) and percentage moisture content (% M.C.) of cotton can be expressed by the equation—

$$\log \text{I.R.} = -A \log \% \text{ M.C.} + B.$$

It is now known that a single value of the slope *A* of this linear function does not suffice for all cottons, nor even for one sample of cotton. The slope may have values between 10 and 12 for the same sample depending upon the previous treatment of the cotton. Further, this equation holds only between about 3% and 10% moisture content—corresponding to a range of relative humidity (hereinafter written R.H.) from 15% to 85% at 25° C. Nearly the whole range of moisture absorption† of cotton between dryness and saturation may be characterised by three equations, as follows—

* It is the practice to compare the electrical insulating quality of different cotton samples by measuring the d.-c. insulation resistance after bringing the samples to equilibrium with 75% relative humidity at 25° C., or at 85% relative humidity at 37.8° C. (100° F.), equilibrium being approached from a lower humidity.

† The word "absorption" is used to denote the taking up of a vapour, "desorption" the giving up of a vapour, and "adsorption" the general process without special indication of gain or loss. The use of these terms implies no assumptions with regard to the mechanism of the processes they denote.

Below 3% moisture content*—

$$\log \text{I.R.} = -A \% \text{ M.C.} + B \quad \dots \quad \dots \quad \dots \quad \dots \quad (I)$$

Between 3% and 10% moisture content—

$$\log \text{I.R.} = -A \log \% \text{ M.C.} + B \quad \dots \quad \dots \quad \dots \quad \dots \quad (II)$$

Between 10% moisture content and saturation (about 25% M.C.)—

$$\log \text{I.R.} = -A \% \text{ R.H.} + B \quad \dots \quad \dots \quad \dots \quad \dots \quad (III)$$

Different values of A satisfy these equations, depending, as noted above, upon the previous treatment of the cotton and upon the direction of approach to equilibrium; whether this approach is from the dry state (along an absorption cycle), or from the wet state (along a desorption cycle). The experimental data include results of tests on one sample of raw cotton and two of water-boiled cotton. The following tabulation gives some idea of the limiting values of A and the conditions under which they will satisfy the equations—

		Equation I		Equation II		Equation III	
		Raw	Water-boiled	Raw	Water-boiled	Raw	Water-boiled
Absorption	...	1.16	No	10.5–11	12	0.143	0.111
Desorption	...	1.06	values†	9.88–10.15	10.2	0.076	0.075

EXPERIMENTAL METHOD

Samples of cotton were brought to equilibrium with a flowing stream of air at 25° C., in which the partial pressure of water vapour could be adjusted to any desired value and maintained constant within 0.0115 mm. This is equivalent to variations of less than 15 parts per million in the water-vapour content of the air, or 0.05% R.H. at 25° C. Insulation-resistance and moisture-content measurements were made at equilibrium‡ for a series of relative humidities in both absorption and desorption cycles on separate samples of the same cotton.

The *moisture content* was determined by mounting about 0.08 gram of cotton, wound in the form of a small skein, on a calibrated quartz-fibre balance, as described by McBain and Bakr.² The sensitivity of this spring was 0.03 gram=1 inch deflection. The deflection caused by moisture adsorption was measured with a cathetometer, calibrated to 0.0001 inch. Measurements were reproducible to 0.0005 inch; thus the moisture adsorbed could be determined to 0.02 per cent.

The *insulation resistance* was measured by mounting 90 threads of cotton, each $\frac{1}{2}$ inch long between metal electrodes, described in a previous communication (No. 15). This sample weighed about 0.05 gram.

The quartz spring was suspended in a long glass tube mounted within an air thermostat. A metal box with a hard-rubber top on which were mounted the electrodes was also contained in this thermostat. The flowing air streams from the same humidity apparatus were passed through the glass tube and the box in parallel.

* Below 2% M.C., the I.R. of even raw cotton is difficult to measure, since it is above the limiting sensitivity (10¹⁸ ohms/mm. at 100 volts) of the insulation-resistance bridge used. Further tests are being made on this low range, using a more suitable type of cotton sample.

† Difficult to measure water-boiled cotton in the range where Equation I might apply.

‡ Below 90% R.H., equilibrium could be practically reached in but two to three hours, using this flowing stream or so-called "dynamic" method. Above 90%, the time for equilibrium increases appreciably, being greater the nearer the test humidity is to saturation. Reference to the data in Table I will show the small differences between two to three hours' exposure and overnight values after 20 hours' exposure.

A continuous record was obtained of the humidity of the flowing air mixture during each experiment, using an exceedingly sensitive humidity recorder, accurate to 0.05% R.H. at 25° C., and sensitive to changes of but 0.02% R.H. The humidity apparatus and the recorder are both described elsewhere.³

Since the humidity apparatus supplied air of fixed absolute humidity, it was essential that constant temperature be maintained in the air thermostat; also that the electrode test box and quartz-spring tube be kept at the same temperature, to insure equilibrium of the samples at the same relative humidity. The *air thermostat* had walls $5\frac{1}{2}$ in. thick, including 3 in. of cork insulation. Copper-constantan thermocouples were mounted in each end of the electrode test-box and in the tube in close proximity to the samples. Efficient circulation of the air within the thermostat, by means of a fan driven from a motor mounted outside the thermostat, together with a sensitive mercury thermo-regulator operating a vacuum tube relay heat control, made it possible to maintain the thermocouples to within 0.01° C. of each other, and the temperature at any point within the thermostat remained constant to at least 0.01° C.

For several years prior to the development of the flowing air stream, or "dynamic" method of testing textiles, insulation-resistance measurements had been made on samples mounted on electrodes in a closed vessel in which 76% R.H. was maintained by saturated NaCl solution. This vessel, in turn, was placed in an air thermostat nearly surrounded by a water bath maintained at 25° C. $\pm 0.1^\circ$ C. Since the atmosphere above the salt solution is relatively stationary as compared with that in the flowing stream method, this procedure is defined as a "static" method. A statistical analysis, made by Dr. W. A. Shewhart of these laboratories, on data taken with both the static and dynamic methods, using samples from the same spool of cotton, clearly showed the superiority of the dynamic method.*

EXPERIMENTAL DATA

Table I contains equilibrium data on moisture content and insulation resistance measurements of raw cotton made at a series of different relative humidities at 25° C., in both absorbing and desorbing cycles. Tables II and III contain similar data for two samples of water-boiled cotton, designated A and B respectively. These raw and water-boiled samples initially came from the same lot of raw insulating cotton.

The arrangement of the data in these tables shows the sequence in which the equilibrium values were obtained.

On Figure 1 are plotted curves showing the relations between (a) % M.C. and % R.H., and (b) log I.R. and % R.H. for the raw cotton data in Table I. Figure 2 contains a single curve showing the relation between log I.R. and log % M.C. for the raw cotton. Figure 3 contains all three of these different types of curves for the two samples of water-boiled cotton. Since the data for these two water-boiled samples checked with one another so well, only one curve of each type was necessary to express the relations for both samples. Figure 4 shows the relation between log I.R. and % M.C. for only the lower

* This analysis has been published by Dr. Shewhart, as an illustration of testing control in a recent book.⁴ His conclusion regarding this analysis was, "We assume, therefore, upon the basis of this test, that it is not feasible for research to go much further in eliminating causes of variability."

Table I

Moisture Content and Insulation Resistance Data on Raw Cotton in Equilibrium with Constant Atmospheric Humidities during Repeated Absorption and Desorption Cycles at 25° C.

Equilibrium Relative Humidity at 25° C. %	Moisture Content		Insulation Resistance per $\frac{1}{4}$ -in. length of 30/2-ply Cotton Thread		
	% M.C.	log % M.C.	megohms	log megohms	
First Cycle of Increasing Humidity—Absorption.					
8.8	2.19	0.340	1.76×10^9	...	9.25
17.6	3.10	0.491	2.18×10^8	...	8.34
26.3 (2 hours)	3.76	0.575	2.21×10^7	...	7.34
26.3 (overnight—20 hours)	3.83	0.584	2.03×10^7	...	7.31
45.7	5.19	0.72	5.81×10^5	...	5.76
61.0	6.49	0.813	6.33×10^4	...	4.80
71.5 (3 hours)	7.61	0.882	8.84×10^3	...	3.95
71.5 (overnight—21 hours)	7.66	0.885	8.61×10^3	...	3.94
82.3	9.39	0.973	1.05×10^3	...	3.02
87.5	11.00	1.041	2.58×10^2	...	2.41
92.7 (6 hours)	13.95	1.145	41.6	...	1.62
93.0 (overnight—24 hours)	14.25	1.154	38.0	...	1.58
99.2	22.30	1.349	5.75	...	0.76
Saturated air (1 hour exposure)	24.50	1.390	4.17	...	0.62
First Cycle of Decreasing Humidity—Desorption.					
93.0	16.90	1.228	15.0	...	1.18
77.2	10.81	1.034	2.45×10^2	...	2.39
56.0	7.50	0.875	8.90×10^3	...	3.95
36.8	5.32	0.726	3.05×10^5	...	5.48
17.6	3.47	0.540	2.22×10^7	...	7.35
11.1	2.61	0.417	2.25×10^8	...	8.35
Samples dried 20 hours with dry air at 25° C.					
Second Cycle of Increasing Humidity—Absorption.					
26.2	3.90	0.591	1.11×10^7	...	7.05
36.2	4.68	0.670	1.39×10^6	...	6.14
56.5	6.47	0.811	3.87×10^4	...	4.59
71.5 (2 hours)	8.35	0.922	3.34×10^3	...	3.52
72.5 (overnight—18 hours)	8.45	0.927	2.79×10^3	...	3.45
Saturated air (6 hours exposure)	30.00*	1.48	2.64	...	0.42
Second Cycle of Decreasing Humidity—Desorption.					
45.0 (2 hours)	6.15	0.79	6.24×10^4	...	4.80
45.0 (overnight—18 hours)	6.08	0.784	6.97×10^4	...	4.84
17.6	3.44	0.537	1.91×10^7	...	7.28
Samples dried 20 hours with dry air at 25° C.					
Third Cycle of Increasing Humidity—Absorption.					
26.2	3.88	0.589	9.95×10^6	...	7.00
Desorption from 26.2% to 5% Relative Humidity.					
5.0	1.72	0.236	5.67×10^8	...	8.75
Samples removed from apparatus and oven-dried at 80° C. for 20 hours.					
First Cycle of Increasing Humidity—after oven-drying.					
45.7	5.07	0.705	4.76×10^5	...	5.68

* Under the "saturated" condition in this case, moisture as dew was visible on the cotton.

Table II

Moisture Content and Insulation Resistance Data on Water-Boiled Cotton in Equilibrium with Constant Atmospheric Humidities during Absorption and Desorption Cycles at 25° C.

30/2 COTTON—SAMPLE A						
Equilibrium Relative Humidity at 25° C.	Moisture Content		Insulation Resistance per $\frac{1}{4}$ -in. length of 30/2-ply Cotton Thread			
%	% M.C.	log % M.C.	megohms	log megohms		
First Cycle of Increasing Humidity—Absorption.						
60.0	6.29	0.80	2.21×10^6	...	6.34	
75.0	8.53	0.93	6.3×10^4	...	4.80	
91.5	13.32	1.12	8.93×10^2	...	2.95	
Saturation	20.70	1.32	9.35×10	...	1.97	
(20 hours exposure)						
First Cycle of Decreasing Humidity—Desorption.						
91.5	15.00	1.18	3.80×10^2	...	2.58	
73.0	10.05	1.00	9.75×10^3	...	3.99	
60.0	7.85	0.895	9.46×10^4	...	4.98	
40.0	5.62	0.75	2.77×10^6	...	6.44	
Samples dried 20 hours with dry air at 25° C.						
Second Cycle of Increasing Humidity—Absorption.						
40.0	4.80	0.68	1.25×10^7	...	7.097	
60.0	6.45	0.81	6.45×10^5	...	5.81	
73.0	8.16	0.91	5.95×10^4	...	4.75	
91.5	13.03	1.11	1.00×10^3	...	3.00	

Table III

Moisture Content and Insulation Resistance Data on Water-Boiled Cotton in Equilibrium with Constant Atmospheric Humidities during Absorption and Desorption Cycles at 25° C.

30/2 COTTON—SAMPLE B					
Equilibrium Relative Humidity at 25° C.	Moisture Content		Insulation Resistance per $\frac{1}{4}$ -in. length of 30/2-ply Cotton Thread		
%	% M.C.	log % M.C.	megohms	log megohms	
First Cycle of Increasing Humidity—Absorption.					
73.0	8.33	0.92	1.08×10^5	...	5.03
60.0	6.33	0.80	2.565×10^6	...	6.41
91.5	12.87	1.11	1.05×10^3	...	3.02
Exposed to air at 100% R.H. overnight—no measurements taken.					
First Cycle of Decreasing Humidity—Desorption.					
73.0	9.86	0.99	8.33×10^3	...	3.92
58.0	7.57	0.88	1.31×10^5	...	5.12
40.0	5.60	0.748	2.78×10^6	...	6.44

range of the experimental data for raw cotton, since up to about 5% moisture content this relation as expressed by equation I on page TI46 appears to hold better than equation II.

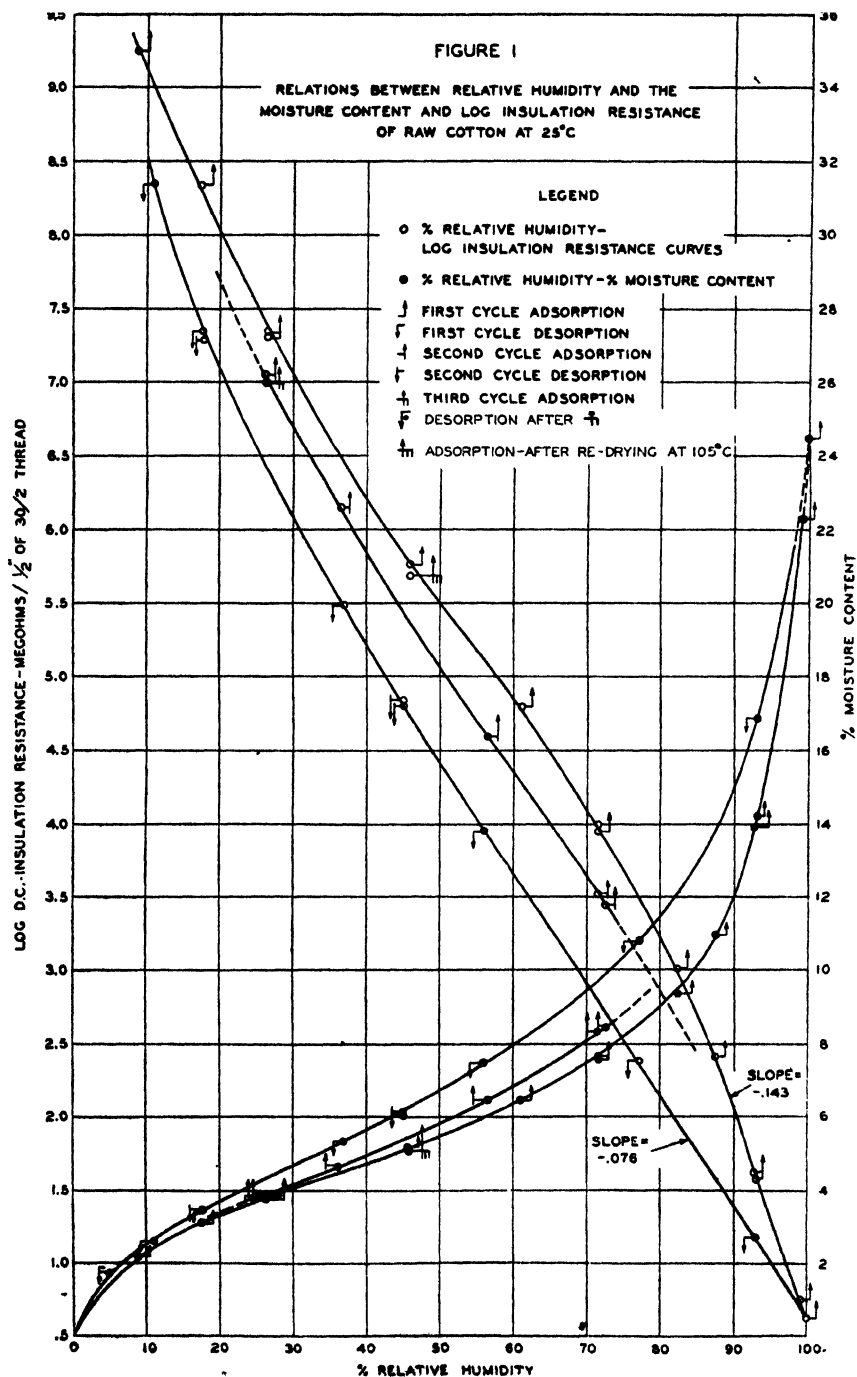
DISCUSSION OF EXPERIMENTAL DATA

Moisture Content-Relative Humidity Data

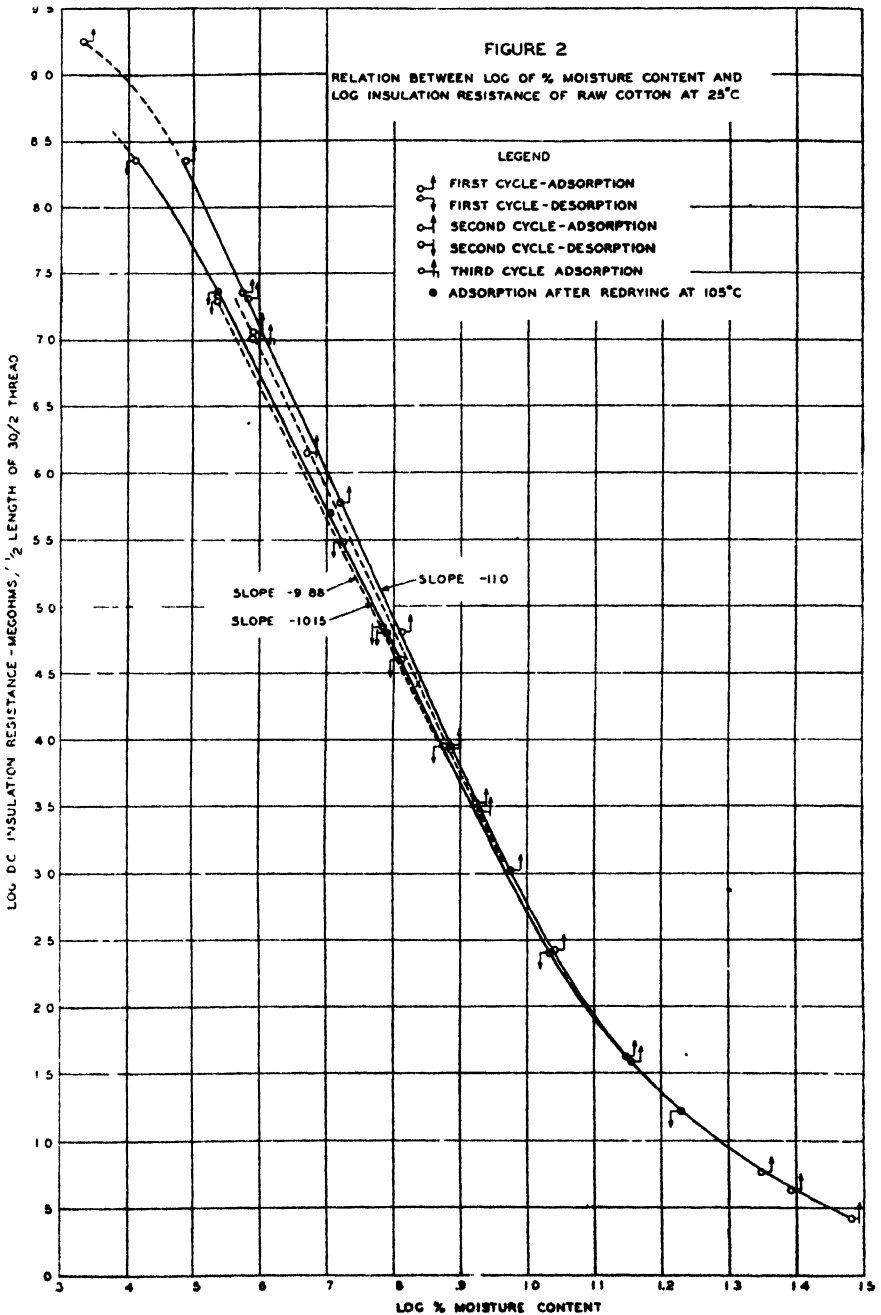
Exposure of raw cotton to a saturated atmosphere causes a reduction in the area of the moisture content-relative humidity hysteresis loop.* See Figure 1. Conversely, no reduction in the area of the loop on successive cycles is observed in the case of water-boiled cotton, perhaps due to this previous water treatment.

* This type of hysteresis loop in the moisture adsorption properties of cotton has been discussed at length by Urquhart and Williams.⁴

Sheppard and Newsome⁶ found reductions in the area of this type of hysteresis loop for a treated cotton on successive cycles of exposure to high and low humidities. Our data show—(a) no change occurs in the position of the absorption curve for water-boiled cotton during two absorption cycles;



- (b) identical desorption curves for two different water-boiled samples;
(c) identical desorption curves for raw cotton in three cycles, as well as a suggestion that the third absorption curve (only one point obtained—at 26% R.H.) coincides with the second absorption curve; (d) a reduction in area in the raw cotton hysteresis loop on the second absorption cycle; (e) this



reduced area for the raw cotton differs but little, both in area and location, from the hysteresis loop for the water-boiled cottons.

This evidence is considered to indicate the close control of the testing conditions made possible with the dynamic method, and suggests that the decreases in area in the loops obtained by Sheppard and Newsome may be due to small variations in thermostat temperature about a mean value. On absorption this would have the effect of giving too high a moisture content at equilibrium, due to hysteresis; on desorption the equilibrium value would be too low.

Insulation Resistance-Relative Humidity Data

Figures 1 and 3 show hysteresis loops in the log I.R.—% R.H. curves, for both raw and water-boiled cotton. Hysteresis loops in this relation were shown in a previous paper (No. 15) but no evidence was available to show the effect on the loop area of exposure of the textile to air saturated with water vapour. From the evidence given in this paper it is seen that exposure to saturated air causes a reduction in the hysteresis loop area for both raw and water-boiled cotton. This behaviour is in contrast to the moisture content-relative humidity relation in which a reduction in loop area is observed for raw, but not for water-boiled cotton.

Between 11% moisture content (about 88% relative humidity) and saturation, the log I.R.—% R.H. relation appears to be nearly linear for raw cotton, and on the desorption curve the relation is linear down to about 45% R.H. For water-boiled cotton, this relation appears to be substantially linear over the full range investigated, from 60% R.H. to saturation on the absorption curve, and from saturation down to about 40% R.H. on the desorption cycle. Curiously, the second absorption cycles for both raw and water-boiled cotton do not exhibit such a linear relation, although in the range above 90% R.H. it is possible that these second absorption curves join the initial absorption curves and become linear in the upper range.

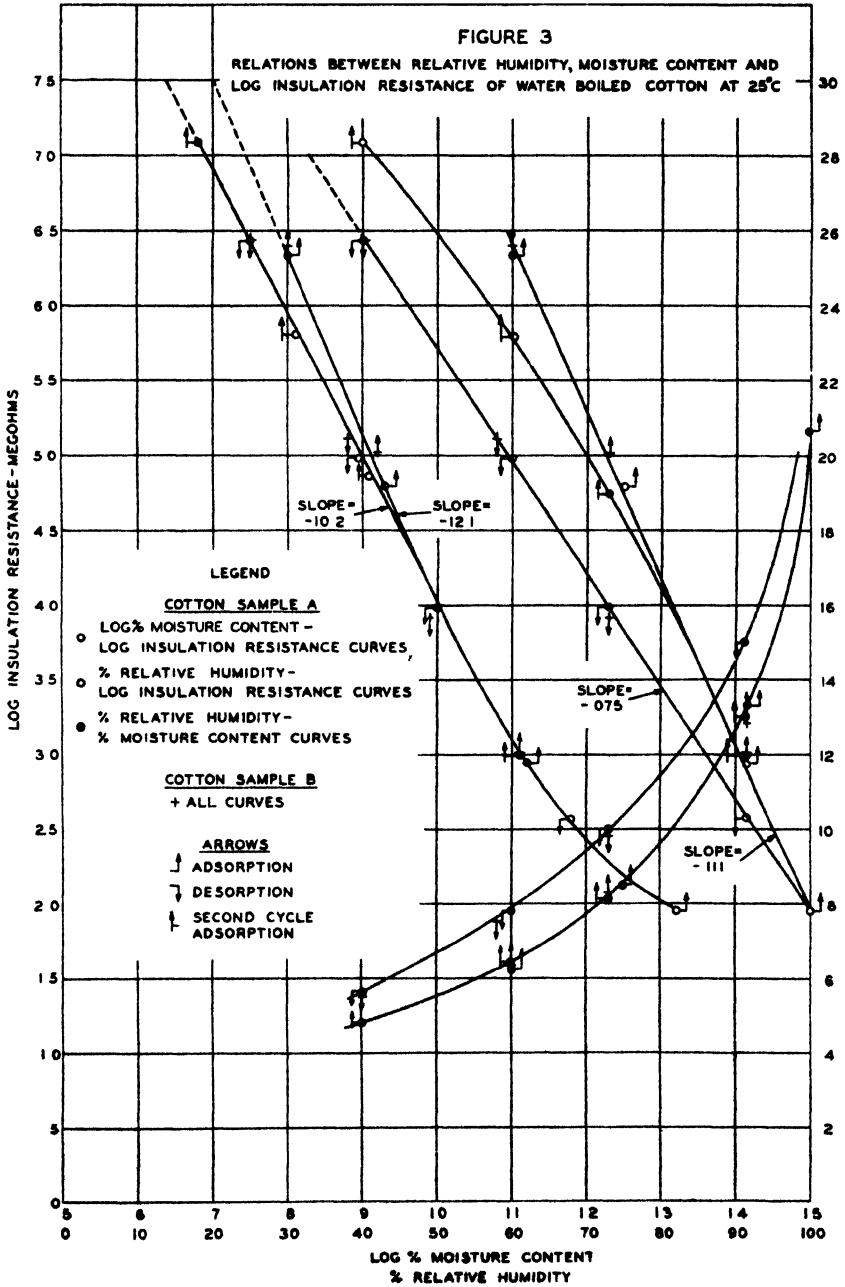
These curves emphasise the necessity for systematic treatment of textiles in making electrical measurements under definite humidity conditions, since the hysteresis in the % R.H.—% M.C. curves indicates that similar hysteresis in the log I.R.—R.H. curves is due to absorption of different amounts of moisture by cotton, even when exposed to the same relative humidity. The amount of moisture absorbed is dependent upon the direction from which equilibrium is approached.

Unfortunately, the behaviour of cotton is still further complicated, so that additional precautions must be taken in measuring its electrical properties.

The difference in the effect of saturation on the area of the hysteresis loops for raw and water-boiled cotton as shown by the log I.R.—% R.H. and % R.H.—% M.C. curves suggests that some change in structure of cotton occurs when it absorbs much moisture, and this change in structure has a more or less permanent effect on the subsequent behaviour of the material. Verification of this suggestion is found in the log I.R.—log % M.C. relation which will now be discussed. The study of this log relation has led to many improvements in methods now employed in the fundamental investigation of the electrical properties of cotton and in inspection methods employed in the commercial purification of cotton for electrical purposes.

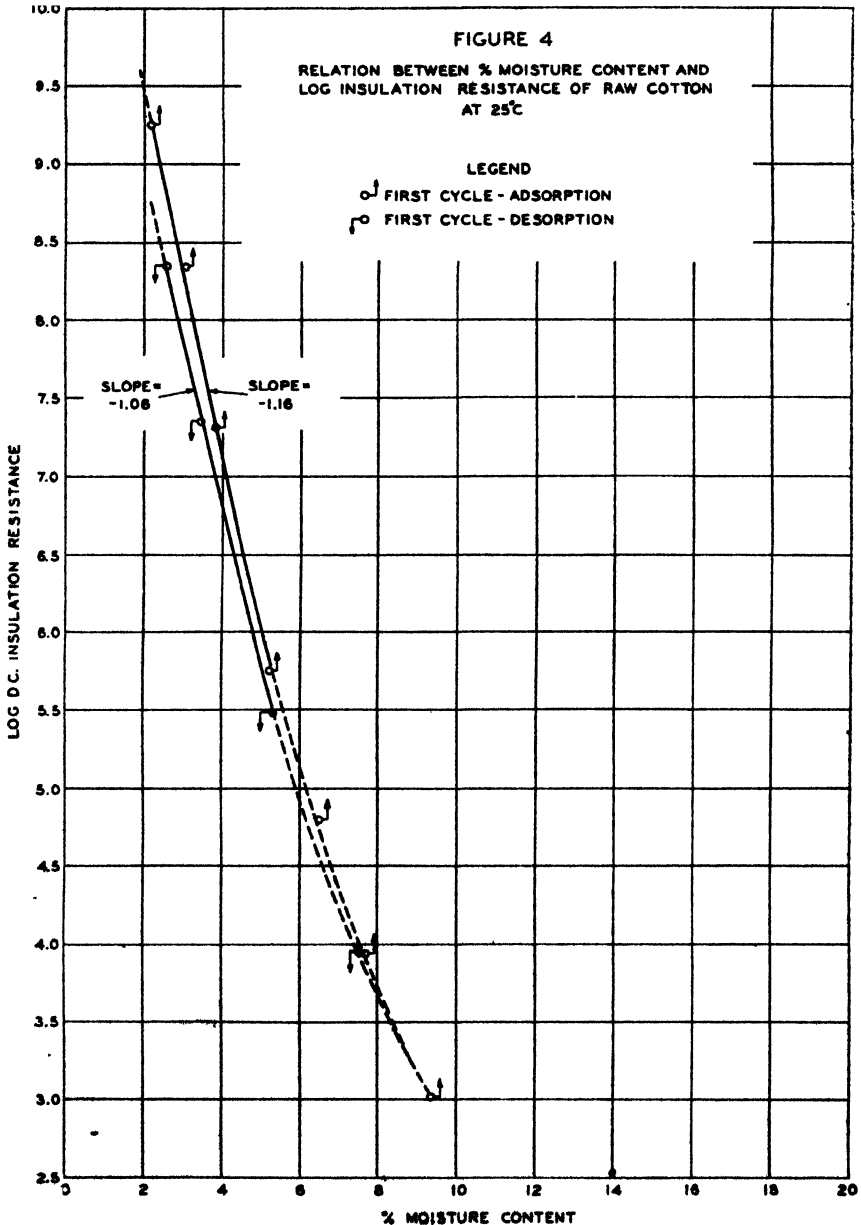
Insulation Resistance-Moisture Content Data

The curves expressing the relation between log I.R.—log % M.C. are shown, in Figures 2 and 3, to be curved, and not linear over the whole range as suggested in an earlier paper (No. 15). The data on raw cotton extends over the wider range, and the curve appears to be sigmoid in shape, exhibiting curvature above 10% and below 3% moisture content. Only in the middle range



between these moisture content limits is the curve sufficiently linear so that equation II applies. The accuracy of the curve below about 5% M.C. progressively decreases, due to difficulties in measuring the extremely high resistances, and about all that can be said of this range at present is that the log I.R.—% M.C. relation expressed by equation I, appears to fit the data better than the log I.R.—log % M.C. relation as expressed by equation II.

The definite curvature above 10% M.C., not observed previously (No. 15), was found through the use of the dynamic method and the measurement



of insulation resistance and moisture content values simultaneously on similar samples of cotton taken from the same supply.*

In the range where equation II is applicable the relation is seen to be a family of convergent lines with slopes (the constant A in this equation) having values between 10 and 12. These convergent lines focus at about 10% M.C. ($\log \% \text{ M.C.} = 1$).† The actual value of the slope A in any test depends upon several factors. It is primarily dependent upon the previous treatment of the cotton. Water-boiled cotton which has been dried from the wet state at high temperature in such a manner as to secure a high I.R. for a given moisture content, in consequence, gives a line with maximum slope. Exposure to high humidities, or saturation of the cotton with water vapour causes the subsequent desorption and absorption equilibrium values to lie on a line of less slope. In the case of raw cotton, the more moisture absorbed by the cotton from a saturated atmosphere, the lower is the desorption value of A; its lower limit appears to depend to some extent upon the time of exposure and the amount of moisture absorbed. (Note the difference in the desorption slope after the first and second exposure of the raw cotton to saturated air. After the first cycle with 24.5% maximum moisture content, $A = 10.15$; after the second with 30% M.C., $A = 9.88$.‡ This difference is greater than experimental error.

Raw cotton shows a distinct difference from water-boiled cotton in one respect. On the second absorption cycle the slope A has a value intermediate between the initial absorption and desorption slopes, thus indicating some reversibility in the properties of the cotton which determine these slopes, due to the drying effect after the initial desorption test. Water-boiled cotton does not show this effect, the slope of the second absorption curve being identical with that of the initial desorption curve, *under the conditions of drying used for these tests*. This behaviour is consistent with some experiments made to determine if the initially high insulation resistance observed in some

* In the vicinity of saturation, an effect similar to polarisation can cause errors in the measurement of insulation resistance. The errors result in high insulation resistance values, accentuating the curvature of the curve above 10% moisture content. This effect is not readily detectable, using the slow-period H.S. type Leeds and Northrop galvanometer. When first found, it was assumed that the entire curvature of the curve above 10% M.C. was due to this effect, but such was not the case. The effect is not true polarisation, but is simply due to electrical heating. Above 90% relative humidity for raw cotton and above 98% R.H. for washed cotton, the measuring current, using 100 volts potential is sufficient to heat the cotton appreciably. This I²R loss can raise the textile temperature about 0.1° C. at 90% R.H., and about 10° C. at saturation for raw cotton. These temperature rises were measured, using thermocouples of No. 40 wire braided into the threads of textile mounted on the electrodes. The heating effect causes evaporation of moisture from the cotton, thus raising the insulation resistance measured.

All measurements in this paper above 75% R.H. for raw cotton and above 90% R.H. for washed cotton were made with a special micro-ammeter having a period of but 0.8 second, as compared with the period of the H.S. type galvanometer of about 40 seconds. The temperature rise at saturation does not become evident for at least three seconds after voltage application. Until this short interval has elapsed the micro-ammeter gives a steady reading identical with the instantaneous value, and as the thermocouple records increasing temperature the meter deflection drops.

† This behaviour is a hysteresis effect of a somewhat different character from that observed in the two relative humidity relations previously discussed, since in this case the effect is independent of relative humidity, and appears to be related to the distribution of moisture in the cotton and to the manner in which this moisture is held by the cellulose. This will be discussed somewhat more fully later.

‡ The value of 24.5% M.C. does not necessarily indicate a true saturation value, but only a M.C. after exposure to a definite saturated atmosphere for one hour. The 30% value probably represents some value above the critical saturation point at exactly 100% R.H. (which would be exceedingly difficult to obtain), since actual deposits of dew were visible on the sample.

cases with water-boiled cotton could be restored by some simple means after the resistance had been adversely affected by exposure to high atmospheric humidities.

In the course of some I.R. tests made on washed cotton the control samples of raw cotton used to check each I.R. experiment to assure the same humidity and temperature conditions were found to have suddenly changed from 4.5 kilomegohms—their normal value under the test conditions—to 1.8 kilomegohms under these conditions. These controls had been exposed to atmospheric humidity conditions of 83% R.H. at 32° C., while a new set of washed cotton samples were being prepared for test. Since it was particularly desirable to continue the use of the same control samples, an attempt was made to restore them to their original conditions by drying. Air at less than 0.1% R.H. at 25° C., was passed over these samples for 40 hours at room temperature. When subsequently measured their resistances had increased from 1.8 to 2.9. Further drying for 48 hours at 105° C. caused a further gain of but

Table IV
Effect of High Relative Humidity (88%) at Different Temperatures on the Insulation Resistance of Cotton at 75% Relative Humidity and 25° C.

Sequence of Equilibrium Conditions	Insulation Resistance of Cotton in kilomegohms per $\frac{1}{2}$ -in. Thread													
	Washed Cotton Samples*									Raw Cotton Samples†				
	1	2	3	4	5	6	7	8	Avg.	1	2	3	4	Avg. (a) exposed to 88% R.H.
75% R.H.—25° C.	73	80	80	90	100	102	100	159	100	4.6	4.8	4.7	4.7	—
88% R.H.—22° C.	9.0	9.8	11.3	12.0	12.0	12.5	9.5	15.0	11.0	—	0.48	0.47	—	0.48
Dried overnight														
75% R.H.—25° C.	46	50	57	60	60	65	57	94	61	4.5	3.0	2.9	4.6	2.95
88% R.H.—30.2° C.	2.4	2.1	2.1	2.6	3.0	2.6	2.6	3.8	2.6	—	0.136	0.138	—	0.137
Dried overnight														
75% R.H.—25° C.	30	31	34	36	36	41	36	58	36	4.3	1.95	1.95	4.3	1.95
88% R.H.—38° C.	1.5	0.84	0.78	1.06	0.96	1.53	1.90	2.3	1.11	—	0.09	0.09	—	0.09
Dried overnight														
75% R.H.—25° C.	22	23	24	29	26	29	31	42	28	4.6	1.7	1.7	4.6	1.7
88% R.H.—22° C.	4.3	4.3	4.7	5.8	5.4	6.3	6.0	7.3	5.5	—	0.43	0.36	—	0.40
Dried overnight														
75% R.H.—25° C.	34	33	34	34	32	38	38	50	37	4.5	2.1	1.8	4.5	1.95

* These samples were washed at 40° C. in accordance with the procedure described in the accompanying paper.⁷

† Two of these raw cotton samples (1 and 4) were used as controls to check the reproducibility of the 75% humidity condition. They were *not* exposed to the 88% humidity conditions. Therefore the averages of 1 and 4 are given under (a). The averages of the other two (2 and 3), which were exposed to the sequence of 88% conditions, are given under (b).

0.1 kilomegohm. Conversely, similar tests on washed cotton showed no improvement. A bundle of washed cotton was dried at 105° C. Instead of giving an I.R. of between 100 and 400 kilomegohms, normal for other similarly washed and dried samples, the resistance was but 23 kilomegohms. Chemical analyses of this cotton gave no indication that this low value was due to electrolytic contamination. Neither redrying of this cotton in a vacuum oven at 80° C., nor drying in an air-oven at 105° C., gave any improvement; in fact the resistance after such redrying was but 18 kilomegohms.

However, this washed cotton was greatly increased in I.R. by simply rewetting with excess water and drying rapidly at 105° C.‡

‡ Samples A and B used to secure the data in Tables II and III were from this test. After rewetting and oven-drying at 105° C., sample A gave 108 kilomegohms and B gave 63 kilomegohms at 75% R.H.—25° C.

From this discussion of the data it is seen that three types of linear equations may be used to express fairly accurately the relation between insulation resistance and the moisture-absorbing properties of cotton over a range of atmospheric relative humidity from saturation down to nearly dryness. These equations, with the respective ranges of relative humidity (and, therefore, of moisture content) over which each is significant, are given on page 1146.

It is concluded that exposure of cotton to high atmospheric humidity causes a change in the gel structure due to absorption of moisture, since the insulation resistance of the material as measured at some comparable condition (75% R.H. at 25° C.) is less after such high humidity exposure than before, even if the cotton is well dried before testing.

The temperature of such exposure to high atmospheric humidity also affects the subsequent electrical properties of the cotton. Data to show this temperature effect are given in Table IV.

TEMPERATURE EFFECTS

Effect of Temperature at High Humidity on I.R. of Air-dried Cotton

Table IV contains the results of a series of tests on the I.R. of samples of raw and washed cotton which were exposed to several cycles of high humidity and dry air, each cycle being as follows—

- (a) Equilibrated and measured at 75% R.H.—25° C.
- (b) " " " 88% R.H.—at t° C.
- (c) Dried for 16 hours with a stream of dry air at 25° C

This cycle was repeated four times, the only difference in each case being the temperature (t° C.) at which the 88% R.H. equilibrium tests were made. These temperatures were successively—22°, 30.2°, 38°, and 22° C. In all, eight samples of washed cotton and four samples of raw cotton were used in the test. Two of the raw cotton samples (1 and 4) were not exposed to the 88% humidity conditions, but were used as control samples to check the reproducibility of the 75% humidity conditions in each cycle.*

Table V is a condensation of Table IV. The decreases in insulation resistance of both raw and washed cotton when measured at 75% relative humidity and 25° C., after exposure to the 88% relative humidity conditions and dried,† are given in percentage of the initial 75%–25° C. insulation resistances.

* Five measurements each were made on these two control samples during the course of the test, giving a mean value of 4.52 kilomegohms, with a standard deviation of but 0.13 kilomegohms.

The differences in the initial values of I.R. for the eight washed samples are not due to lack of control, either in the method of washing or in the method of testing, but to actual differences in the equilibrium moisture contents. For example—sample 1 gave 73 kilomegohms initially, and sample 6 gave 102 kilomegohms. Their respective moisture contents, under the test conditions, were 8.17% and 8.00%.

Using Equation II, and with the constant $A=10$, the values of B were calculated in this equation as 13.99 and 14.05 respectively for samples 1 and 6. Assuming these samples to be of equal purity, since they were washed in an efficient manner (see accompanying paper¹) it is reasonable to take $B=14.03$ for both samples. From this value of B , the I.R. of sample 1 was calculated at a moisture content of 8.00%, giving 98 kilomegohms, a satisfactory check with sample 6 at the same moisture content.

† The samples were dried with a stream of very dry air at 25° C. after each exposure to the 88% humidity conditions to avoid the hysteresis effect, which would occur if the samples were brought back to the 75% humidity condition directly from the higher humidity. Before starting the test all samples were similarly dried.

Table V

Percentage Reduction in the Insulation Resistance of Raw and Washed Cottons at 75% Relative Humidity and 25° C., after Successive Exposures to 88% Relative Humidity at t° C.

Temperature (t° C.) of the successive 88% R. H. Cycles	% Reduction in Insulation Resistance at 75% - 25° C. after each 88% R. H. Cycle		
	Washed		Raw
22° C.	39%	...	37%
30.2° C.	64%	...	58.5%
38.0° C.	72%	...	64.5%
22° C.	63%	...	59.5%

Exposure of cotton to high humidity (in this case 88%) alters the properties of the material in such a way that its insulation resistance when subsequently measured at 75% relative humidity and 25° C., is lower than the insulation resistance measured at the 75% condition before such exposure to 88% humidity. This decrease in insulation resistance observed at 75% humidity and 25° C., becomes progressively greater the higher the temperature of the 88% humidity exposure, but on again exposing the cotton to 88% humidity at the reduced temperature of 22° C., after exposure at 38° C., the insulation resistance subsequently measured at 75% humidity and 25° C., is greater than after the 88%–38° exposure, but less than when measured at this condition after the original exposure to 88% humidity and 22° C., thus indicating that some reversal occurs in the temperature effect.

The fact that in each test the percentage reduction is of the same order of magnitude for raw and washed cotton, suggests that the effect is structural and not related to the quantity of electrolytic impurities which may be present.

An important feature of the data recorded in Table IV is that the insulation resistance of washed cotton is reduced by exposure to 88% R.H. A natural question is—What would be the resistance of this cotton if exposed to 100% R.H. instead of 88%, or brought directly to equilibrium with 75% R.H. at 25° C., from the wet state without oven-drying? Tests have been made to determine these points. Washed cotton, dried at 105° C., then conditioned at 100% R.H., gave an I.R. when tested at 75% R.H. at 25° C., of 25 kilomegohms.* Its insulation resistance on being brought directly from the wet state to 75% R.H. at 25° C., was but 3.7 kilomegohms, being in this case lower than the resistance of raw, unwashed cotton in Table IV. Of course, if the raw cotton could be wet with water without undergoing any change due to reduction in ash content, no doubt its resistance would be much lower than that of similarly treated water-washed cotton, since this effect appears to be structural and certainly is not dependent upon electrolytic impurities.

Effect of Temperature of Drying Wet Cotton on its Insulation Resistance

The higher the temperature at which wet, water-boiled cotton is dried, the higher is its insulation resistance. Such cotton, dried at 105° C., 120° C., and 162° C., from the wet state, gave 139, 171, and 201 kilomegohms respectively, when subsequently equilibrated at 75% R.H. at 25° C.

* This oven-dried material gave 80 kilomegohms when not exposed to the 100% R.H. before test.

THEORY

The most important fact to be derived from these experimental data is that cotton may have a range of insulation resistance values for any single moisture content over at least the average atmospheric humidity range, from about 15 to 85% R.H. Another interesting fact is that the insulation resistance of cotton when measured at definite test conditions depends to a surprising extent upon the previous exposure of the material to prevailing atmospheric humidity and temperature conditions, prior to such tests.

This behaviour suggests that the absorption of appreciable quantities of moisture causes changes in the cotton structure, which affect the mechanism of current conduction. This change in structure, no doubt a result of swelling, an effect investigated by Collins,⁸ appears to be a difficultly reversible alteration in the colloidal gel structure of the cellulose, even after subsequent removal of the moisture by drying. These effects, rather small to be detected by ordinary methods, are revealed by the extremely sensitive electrical tests, since very small changes in moisture content cause large changes in insulation resistance.

Since the substitution of acetyl for hydroxyl groups in cellulose is accompanied by a marked reduction in the moisture adsorption,⁹ it appears likely that adsorption of moisture is largely a function of free hydroxyl groups. From our data it appears that when wet cotton is dried rapidly at high temperatures, the internal or micelle surface contains a minimum of hydroxyl groups. As the cotton is permitted to absorb more and more moisture, the hydroxyl groups which were oriented into the interior of the micelles by the drying process where their hygroscopic property is, in effect, neutralised by attraction of associated molecules, are attracted to the surface to hold the absorbed moisture. On drying, these hydroxyl groups do not return readily to the interior and a greater number of water molecules are held at any relative humidity, thus accounting for the normal hysteresis effect observed in the moisture content-relative humidity relation.

Practically all of the experimental data discussed in this paper were secured during 1928 and 1929, and the above theory was proposed at that time. Apparently at about the same time Urquhart questioned the explanation offered some years previously by Urquhart and Williams¹⁰ to account for hysteresis in the moisture relations of cotton, depending upon a modification of the Zsigmondy pore theory. In June 1929¹¹ Urquhart proposed a theory comprising the essential features of the orientation of hydroxyl groups as offering a better explanation than the pore theory for the moisture-adsorbing properties of cotton. The general outline just given in connection with the study of the electrical properties of cotton is much the same as the more complete theory discussed by Urquhart.

However, further consideration of our experimental data led to the conclusion that neither the pore theory nor the orientation of hydroxyl groups completely accounts for the hysteresis effect in the $\log I.R. - \log \% M.C.$ relation.

As mentioned above, rapid drying of wet cotton under proper conditions is assumed to give internal surfaces containing a minimum of hydroxyl groups. This idea can be qualified as follows—Either such drying conditions are conducive to the presence of a minimum of hydroxyl groups on the internal surfaces, or they are conducive to a *less uniform distribution* of these groups on these internal surfaces.

Consequently, on initially absorbing moisture from such a dried condition, the moisture associated with hydroxyls will not be uniformly distributed and the conduction of current through the cotton along these internal surfaces will be somewhat *discontinuous*. On desorption from saturation, moisture will be removed in a more regular fashion from more uniformly distributed hydroxyls, and therefore on any descending curve the conduction of current can be considered to be along more continuous paths. This difference in continuity of moisture paths is sufficient to account for high insulation resistance values on absorption and low values on desorption curves, for each equilibrium moisture content. The actual insulation resistance in any given case depends upon the degree of continuity of such moisture paths and this in turn depends upon the previous treatment of the material.

Also it seems reasonable to consider that some of the properties of cotton under discussion may be explained to better advantage by the pore theory initially proposed by Urquhart and Williams,¹⁰ since it does not appear that all of the moisture which saturated cotton can absorb is necessarily associated with hydroxyl groups. In considering the pore theory, high insulation resistance values during absorption can be accounted for by a blocking effect of the pore entrances by a few water molecules. This pore blocking effect suggested by Peirce¹² would cause greater discontinuities in moisture paths through the cotton, and therefore higher insulation resistance for a given moisture content.

Since it is planned to discuss this theory more in detail in a separate paper when experimental data now being secured are available, only the above brief outline is given at this time.

Acknowledgments are made to Mr. M. H. Quell, Mr. H. S. Davidson, and Mr. G. E. Kinsley for their valuable assistance in securing the data reported in this paper.

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18—THE PRE-NATAL CHECK IN THE BIRTHCOAT OF THE NEW ZEALAND ROMNEY LAMB

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Forwarded by the Wool Industries Research Association

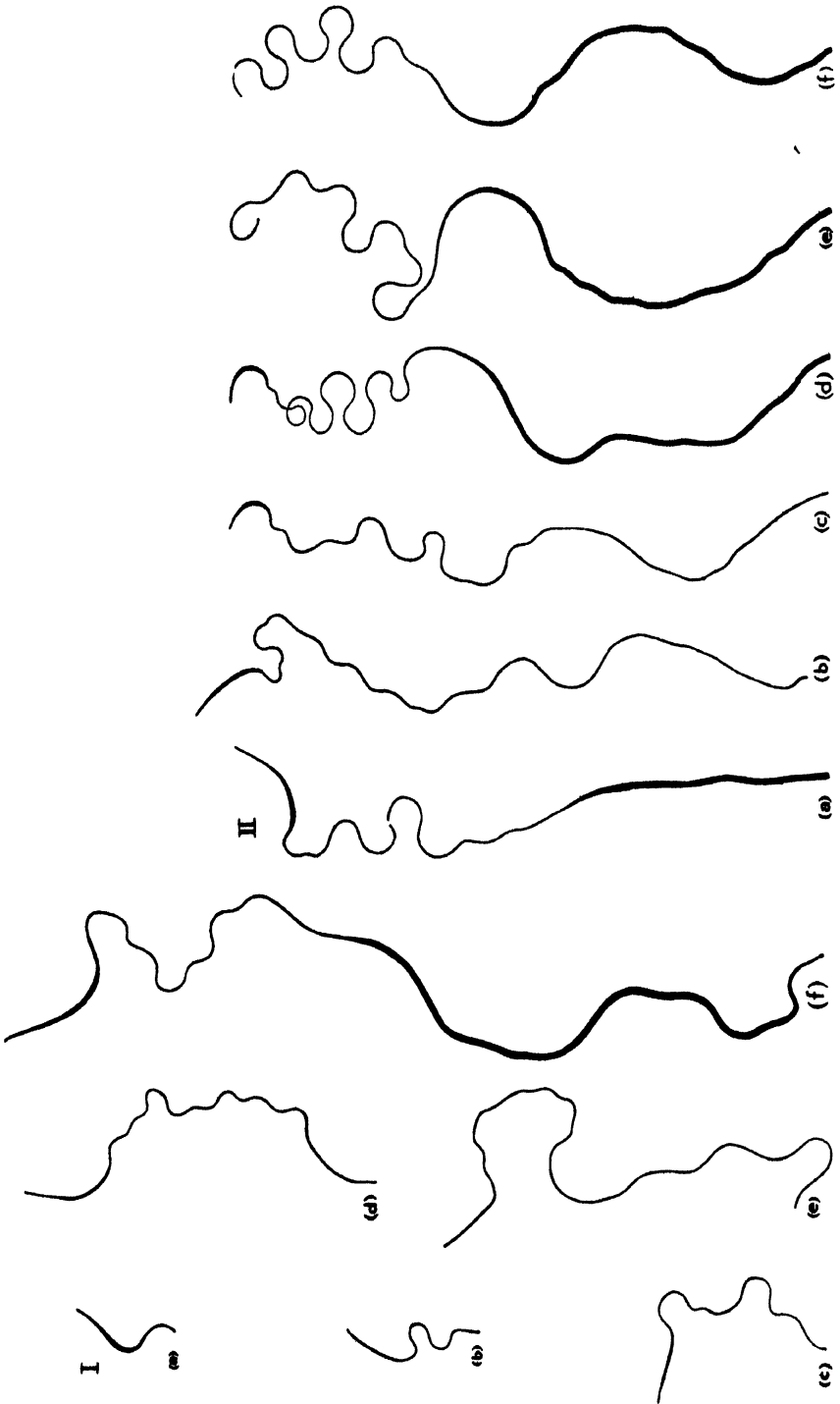
In his work on the coverings of birds and mammals Prof. J. E. Duerden has shown what admirable material are feathers and hairs for studies of growth and form that are of fundamental interest to genetics and phylogeny. His recent letter to *Nature* emphasises this anew. The main interest in zoological work on wool lies in attempting to explain, in one set of terms or another, how the coat of the sheep comes to be what it is. Certain facts about the coat of the New Zealand Romney lamb are presented in the hope that their eventual interpretation will contribute to what may be called the zoological theory of the fleece.

Whatever interpretation be adopted, the similarity between the birthcoat and a down coat is increased by the frequent presence of shed sickle-fibres in the coat of the new-born lamb (Fig. 1, *a, b, c*). Prof. Duerden¹ figures similar fibres in the Merino. These fibres are shed, not broken, because occasionally the brush at the basal end is enclosed in a little sheath, as often happens with kemps (halo-hairs sickle-fibres, and associated types) shed after several weeks of post-natal growth. Sickle-fibres that have ceased to grow before birth may be called "baby sickle-fibres." The length of the fine region below the sickle-end varies greatly, sometimes being very short indeed. "Infant sickle-fibres" (Fig. 1, *d, e*,) are shed, judging from their length, after growing for just a short time after birth. They are much shorter than the sickle-fibres that cease to grow about the age of two months after the production of a medullated region some three or four centimetres in length. (Fig. 1, *f*). Curly tip fibres, similarly regarded as babies and infants, have been found in very small numbers.

Professor Duerden's conception of heterotypism (the possession of a sub-apical region coarse compared with the finer part below) as the primary condition of the hair fibres in most mammals is an illuminating one. With attention concentrated upon sheep that must be shorn at annual intervals it is easy to forget that persistent growth is exceptional and that mammalian hairs usually grow for a limited time, often no more than a few weeks. Most mammalian hairs attain their maximum area of cross section quite early, and their rate of increase in length at the same time is probably high. To cite evidence upon growth rate from the sheep itself, my colleagues R. Waters and B. L. Elphick have shown by dyeing at intervals that the coarsely medullated part of a fibre grows faster, sometimes much faster, than the fine, non-medullated part of the same fibre. With the completion of a mammalian hair the rate of output of material from the follicle does of course fall to zero, and as this cessation of growth is approached the fibre becomes thinner, and often a considerable length of the fibre is appreciably finer than the stoutest portion nearer the tip.

As the growth of the first year's coat of the Romney lambs studied has continued, nearly all birthcoat fibres that are at all coarse after birth have sooner or later become appreciably finer. Such thinning is in addition to the temporary thinning at two to three months after birth that occurs in some fibres in place of shedding.

I believe that the coarse fibres of a mammal tend to be more primitive than the fine ones. Thus in rodents the fine zigzag fibres would appear



PLATES I AND II

specialised. In *ornithorhynchus* the stoutness of the apical region of the large fibres appears to me very suggestive, for part of this broad shield has small scales in the form of the shingles of a roof, a scale pattern that may be regarded as primitive in the extreme. Whether this view about coarseness being primitive be correct or not, it is a general rule, as de Meijere² especially has shown, that in the original pelage of a mammal the earlier a fibre begins to grow the stouter it is. In fibres starting their development relatively early comparative fineness of a portion, or of the fibre as a whole, therefore calls for explanation.

I agree with Prof. Duerden that the pre-natal portion of a curly-tip fibre with post-natal medullation may usefully be regarded as having lost its medulla in the course of evolution, but I think that the idea of loss must be applied to the basal as well as the apical part of the pre-natal curly region, and also to the fine pre-natal part of the sickle-fibres. This idea of loss or suppression is also extended to the post-natal region of some sickle-fibres and curly-tip fibres now to be considered.

In an earlier communication³ I referred to differences in the fibre type arrays in the birthcoat of Romney lambs. This classification centres on the kind of transitional series into which fibres can be arranged in order to link by gradual steps sickle-fibres possessing big sickle-ends with the coarsest curly-tip fibres. To the several arrays names taken from topographical features are given. These were suggested by K. M. Rudall who is working with me. It is to be understood that arrays exist that occupy intermediate positions in this scheme of classification.

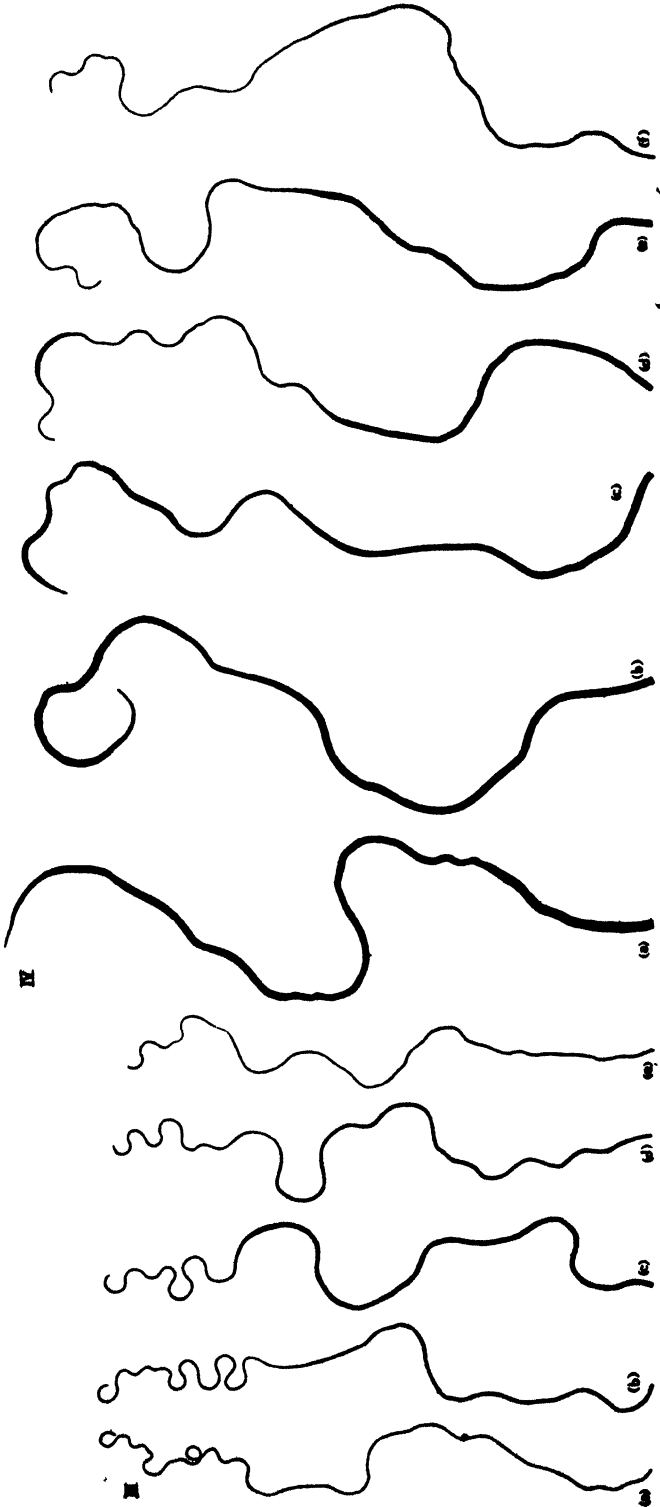
In the simplest array containing sickle-fibres, these fibres and the curly-tip fibres with the longest tips are all coarsely medullated after birth, the transition being made by a gradual decrease in size and final complete disappearance of the sickle-end. This array is named "Saddle" to distinguish it from the "Plateau" array to be described a little later.

In the "Ravine" array there is a direct transition from small-ended sickle-fibres with post-natal medulla to similarly medullated curly-tip fibres, but within the sickle group, as one proceeds from the big-ended fibres to those with smaller ends, there is a reduction in coarseness followed by a rise (Fig. 2). Both in this array and in the next the fineness of some sickle-fibres may be very striking.

In the "Valley" array (Fig. 3, *a*, *b*, *c*) the depression extends from the sickle group to the curly-tip fibres. Those with most curls in the tip are finer than the ones which follow them along the series, being often especially fine, while the coarsest curly-tip fibres sometimes have comparatively short tips. The fine fibres at the beginning of the curly-tip series are called "checked" curly-tip fibres. They are a key type for purposes of classification. They prove to be common enough, but I had not recognised them when the early account⁴ to which Prof. Duerden makes reference was written.

In the array called "Plain," found only in specimens of wool fine for the Romney breed, there is very little increase in coarseness in the passage from fine sickle-fibres to the coarsest curly-tip fibres. It is difficult to draw a definite line between Valley and Plain.

The Plateau array (Fig. 4) is found in some very coarse wool specimens that are strongly medullated. Here the transition is direct from halo-hairs to curly-tip fibres. Many curly-tip fibres have a greater or less amount of medulla in the pre-natal region, but fibres with the definitely sickle-shaped



PLATES III AND IV

tip are not found. Occasionally in other arrays a certain amount of medulla, coarse enough to be detected by the naked eye, occurs in the tips of the coarsest curly-tip fibres.

In all arrays the coarsest curly-tip fibres are followed along the series by finer curly-tip fibres with fewer curls. (Fig. 3, *d*, *e*), and these by fine fibres without definite curls in the tip. From observations at birth and from the preliminary examination by Miss Nancy Galpin of pre-natal material it is evident that the order in which the fibre types have been given in describing an array is very much the order in which they start to grow, while the large birthcoat kemps, the halo-hairs, are probably the first fibres of all to begin their development. Many lambs have no halo-hairs on the back. In many of the lambs sickle-fibres are all fine after birth, and the sickle-ends may be very small indeed.

The five arrays described have all been found in different lambs at the standard position on the back, that is, the middle line at the level of the last rib. Valley has proved the commonest array there, and Plateau the rarest. Plateau is more common on the britch, not only low on the leg but higher, where the coat grows long; in one lamb this array was found in all parts of the body examined, namely, the back, side, poll, britch, brisket, and tail.

Different parts of the body very commonly have different fibre type arrays. Valley on the back is even accompanied in some lambs by Plateau on the britch. In distribution over the body Miss Galpin has established that there are orderly relations in fibre type array. It may be mentioned that in her studies of pre-natal material she finds that the early development of the coat proceeds in the manner recently described by Wildman⁶, and the fact stands out that in different regions sickle-fibres pass through the same stage of development at different times.

In contemplating the fibre type arrays we recognise that along the series, from halo-hairs to the fibres without curly tips beginning to grow about birth or afterwards, the trend is from coarse to fine. Superimposed upon this gradual falling off in coarseness are the effects of what I have called the "birth-check," though the term "pre-natal check" seems better. If the growth of the fleece has proceeded far enough the latter thinning of birthcoat fibres that are coarse after birth is also in evidence.

As effects of the pre-natal check are included the following—the shapely narrowing of the basal part of any sickle-ends which are at all coarse, the fineness of the rest of the pre-natal region of sickle-fibres, the shedding of baby and infant sickle-fibres, the fineness of the tips of curly-tip fibres, and the fineness of the post-natal region of fine sickle-fibres and checked curly-tip fibres. The halo-hairs of regions where they are long show sub-apical thinning more or less accentuated, which is also to be looked upon as an expression of the same check. This occurs in the halo-hairs of even the Plateau array (Fig. 4, *a*, *b*) where the effects of the check are the least marked, and in the same array the tips of many coarser curly-tip fibres are appreciably fine, and those of the smaller curly-tip fibres are fine like those of other arrays.

Two other effects attributed to a powerful pre-natal check may be mentioned. As explained previously⁶, a powerful check is thought to be an important factor in bringing about persistent growth, instead of cessation of growth after about two months, of many sickle-fibres with a coarse

post-natal region. The shedding of these fibres I regard as an expression of vigorous growth, and if that be so their shedding is a very different matter from that of baby sickle-fibres.

The influence of the check has been found by Miss Anthea Hefford to extend also to the sweat glands. In one lamb she found that the follicles of some checked curly-tip fibres lacked sweat glands or had sweat glands small compared with those of the sickle-fibres and coarse curly-tip fibres placed next to them in the series. In this wool specimen the pre-natal check was shown by the fibre type array, a Valley array with special features, to be very marked in its effects.

As I have acknowledged before, this extended use of the idea of the pre-natal check follows upon a demonstration by Prof. Duerden of the pre-natal thinning in sickle-fibres. I believe that this feature of sickle-fibres, and the apical fineness of curly-tip fibres, may be looked upon as two expressions of a suppressing force, or resultant of forces, that produces a widespread inhibiting effect. In the light of facts that have been given it seems to me best to regard the pre-natal check as a specialised phenomenon, not a primitive one, but to trace its evolution in mammalian hair wide comparative studies are needed.

What this check may be and how it works is the subject of a good deal of speculation in my laboratory. It is an obvious suggestion that the features taken as indicative of a more severe pre-natal check have arisen as the accompaniment of increasing density or of increasing density at some pre-natal developmental stage.

The economic objective at textile and agricultural research institutions necessitates detailed comparative studies, and when efforts are made to answer questions of the kind now under discussion the interest of these investigations extends to fundamental biological problems.

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- ¹ *J. Text. Inst.*, **18**, 1927.
- ² *Morph Jahrb.*, **21**, 1893.
- ³ *Nature*, **127**, 482, 28th March, 1931.
- ⁴ *Bul. W.I.R.A.*, vol. 2, No. 2, 1931.
- ⁵ *Proc. Zoo. Soc. Lond.*, 1932, Pt. II.
- ⁶ *Nature*, **129**, 904, 18th June, 1932.

DESCRIPTION OF PLATES

PLATE I—*a* to *c*, baby sickle-fibres; *d*, *e*, infant sickle-fibres; *f*, sickle-fibre, with coarse post natal region, that ceased to grow about eight weeks after birth.

PLATE II—*a* to *f*, series of fibres to show distinguishing feature of Ravine array.

PLATE III—*a* to *c*, series of fibres to show distinguishing feature of Valley array; *d*, *e*, curly-tip fibres that by comparison with *c* are fine and have short tips.

PLATE IV—*a* to *f*, series of fibres of Plateau array.

Note—In all the figures diameter differences are exaggerated.

19—THE DETERMINATION OF THE ACETYL CONTENT OF CARBOHYDRATE ACETATES

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SUMMARY AND THEORY OF THE DETERMINATION

The determination of the acetyl content of carbohydrate acetates is an operation of some importance for industrial as well as for purely academic purposes. From the point of view of the textile industry it is important, first, in the control of the manufacture of acetate rayon and of "immunised" cotton, and secondly, in the control of the finishing processes involving the partial or complete hydrolysis of these materials. There is thus a need for an examination of methods that may be used for the purpose; the present paper describes a method that has some advantages over those now in common use.

This method relies on the hydrolysis of the acetylated carbohydrate by means of sulphuric acid. Separation of the acetic acid formed from the sulphuric acid used is effected by extraction of an aliquot part of the hydrolysis mixture with ether, in which sulphuric acid is insoluble. A fraction of the ether extract is then titrated with caustic soda solution and concentrations and volumes are so arranged that the solution to be titrated contains roughly one-twentieth of the acetic acid formed from the sample taken for analysis. As a result, 0.5 gram of an ordinary cellulose acetate rayon requires about 20 c.c. of *N*/100 caustic soda for the titration.

The literature on this subject has been summarised by Krueger,¹³ so that a brief mention is all that is necessary here. Existing methods for the determination of the acetyl content of organic compounds rely on the removal of the acetyl groups by acid or alkaline hydrolysis, and measurement of the acetic acid or its salts by direct or indirect methods. Hydrolysis by alkali has been used by Cross and Bevan⁴ (sodium ethoxide), Green and Perkin,⁸ Schultze and Hess²³ (methyl alcoholic ammonia), Schwalbe²⁴ (cold aqueous alkali), Irvine and Hirst¹¹ (warm aqueous alkali), Eberstadt,⁵ Knoevenagel and König,¹² Ost and Katayama¹⁸ (aqueous alcoholic alkali), Barnett¹ (acetone-aqueous alkali), Battegay and Penche² (pyridine-aqueous alkali), and Moehring¹⁴ (sulphydrates). Acid hydrolysis has been employed by Perkin¹⁹ (alcoholic sulphuric acid), Ost,¹⁷ Ost and Katayama¹⁸ (50% aqueous sulphuric acid), Fenton and Berry⁶ (phosphoric acid), Sudborough and Thomas²⁵ (aromatic sulphonc acids), Pregl and Soltys²¹, and Freudenberg and Weber⁷ (toluenesulphonic acid).

Both methods have disadvantages. The hydrolysis of acetylated cellulose by alkali is a heterogeneous reaction between a solution and a bulk solid, and there is a danger that part of the material may escape hydrolysis. Furthermore, cellulose, being feebly acidic, clings tenaciously, particularly when swollen, to small quantities of caustic alkali, so that the end-point of a titration of an alkaline solution containing cellulose is always indefinite. The use of strong acids for the hydrolysis is less disadvantageous since they are capable of completely dispersing the acetylated cellulose. Their use, however, introduces another difficulty, that of separating the acetic acid formed from the large excess of strong acid used for effecting the decomposition. The standard method is, of course, distillation in steam, but this is clumsy and tedious, and in the final stages of the distillation the volatile acid is

separated very slowly so that the bulk of the distillate is inconveniently large for titration. It is also possible that prolonged contact of cellulose with hot acid results in the formation of volatile acids and leads to inaccurate figures on this account.^{10, 22}

It is clear, therefore, that there is a definite need for a rapid and accurate method for determining the amount of acetic acid obtainable from acetylated celluloses. A survey of many possible methods indicated that the most promising one is that which involves hydrolysis of the material with fairly concentrated cold sulphuric acid followed by the isolation of the acetic acid produced by extraction with ether. Pinnow²⁰ has investigated the distribution of acetic and other organic acids between ether and water, and methods involving extraction with ether have been suggested by several workers for the estimation of acetic and other organic acids.^{3, 15, 16, 26, 27}

The method described in this paper is rapid, easy, and accurate. It owes much to the work of earlier investigators, but has been simplified and developed specifically for textile purposes. Its chief advantage over the classical method employing acid hydrolysis and steam distillation lies in the fact that many samples can be dealt with simultaneously by one operator. It is possible, for example, for one person to carry through a dozen determinations at one time by this method, an operation that would require an impracticably large amount of apparatus and bench space if it were attempted by the steam distillation method. The method is an absolute one and the experimental constant is found to be the same for all the carbohydrate acetates examined, provided that ether purified as described is employed.

Acetic Acid Yield and Degree of Hydrolysis

The composition of an acetylated cellulose can obviously be expressed in various ways, but it is considered that the most generally useful method is to calculate the quantity of acetic acid obtained by complete hydrolysis of the ester part, and it is proposed to denote the quantity of acetic acid so obtained by the term "acetic acid yield." This is conveniently expressed as a percentage on a dry basis. Thus an acetylated cellulose with an acetic acid yield of 52% means that from 100 grams of the dry material, 52 grams of acetic acid can be obtained by hydrolysis.

The acetic acid yield of commercially available acetate rayons is found in practice to vary within comparatively narrow limits, but it frequently happens that such material is partially hydrolysed, either accidentally or deliberately in order to obtain definite effects in finishing. With cellulose acetate rayons, the hydrolytic process effects the removal of the acetyl portion of the compound and leaves a residue of cellulose. This action takes place from the outside of the filament inwards, and may be accompanied, if sufficient care is not taken, by some loss, by mechanical means, of the regenerated cellulose. Although it is desirable, therefore, to have some figure that will express the extent of hydrolysis, it will readily be seen that no account can in general be taken of possible loss of cellulose during hydrolysis, so that any figure denoting extent or degree of hydrolysis must be accepted with caution.

If these facts are borne in mind, such a figure may be calculated from the acetic acid yields of the rayon before and after the partial hydrolysis. This figure can give no detailed information about the actual physical or chemical state of the material, but must be regarded simply as a convenient summary of the analytical measurements. For this purpose it is convenient to regard

the composition of the original unhydrolysed material as the basis for calculation, and to represent the final, partially hydrolysed material as a mixture of the unchanged substance and cellulose. The degree of hydrolysis is then calculated as the percentage amount of the original acetylated cellulose that has been completely hydrolysed to cellulose.

Commercial acetylated celluloses are not definite chemical compounds, but may be represented by the general formula $C_6H_{10}O_5(C_2H_2O)_n$, where n is not necessarily an integer.

The partial hydrolysis of such a material may be represented by—



The partially hydrolysed substance $C_6H_{10}O_5(C_2H_2O)_n$ may be considered as equivalent to $x[C_6H_{10}O_5(C_2H_2O)_n] + y C_6H_{10}O_5$. The degree of hydrolysis is then $100 y$ or $100 (1-x)$. The acetic acid yield of $C_6H_{10}O_5(C_2H_2O)_n$ is $6000n/(162+42n)=A_1$ and of $x[C_6H_{10}O_5(C_2H_2O)_n] + yC_6H_{10}O_5$ is $6000nx/(162+42nx)=A_2$.

By eliminating n we get—

$$x = \frac{A_2}{A_1} \left(\frac{1000-7A_1}{1000-7A_2} \right)$$

when the degree of hydrolysis

$$H = \frac{100,000 (1-A_2/A_1)}{1000-7A_2}$$

EXPERIMENTAL TECHNIQUE

(i) Solution and Hydrolysis

Half a gram of the well-sampled acetylated cellulose, cut up if necessary, is weighed out into a bottle provided with a stirring rod stopper. The moisture determination is made upon another sample, or if preferred, the samples are dried before weighing. Drying at 110° C. for six hours has no effect upon the acetyl content. Five c.c. of 65% sulphuric acid (made up as indicated below) is added from a burette or graduated pipette and the mixture well stirred. The bottle is then placed in a rack in a thermostat at 30° C. and left with occasional stirring for five hours. The acetylated cellulose dissolves after one to two hours, and the solution gradually darkens to a yellow-brown colour. This solution is then washed into a round-bottomed 100 c.c. flask, about 30 c.c. of water being added in all. The neck of the flask is well ground to fit the lower end of a straight tube Liebig condenser similarly ground. A glass bead is added and the liquid is gently boiled over a small flame for 15 minutes. The flask is then cooled and the contents made up to 50 c.c. in a standard flask. The diluted solution should be clear or have only a slight precipitate. If it is possible to leave the diluted samples overnight, there is no need to heat them under reflux.

(ii) Extraction and Determination of Acetic Acid

Ten c.c. of the diluted liquid are introduced by means of a pipette into a 30-c.c. narrow-necked bottle with a well-fitting stopper. Twenty c.c. of ether (purified as described below) are now added from a pipette connected by an unlubricated three-way tap to a supply bottle kept in a thermostat at 20° C. The stopper is well fixed in, the bottle is well shaken for 30-60 seconds and is then partially immersed in the thermostat at 20° C. and left for one hour. The bottle is then carefully taken from the thermostat, its stopper removed, and placed upon the stand A (Fig. 1) immediately below

the pipette B. The stand is now gradually raised until the tip of the pipette is well within the ether layer. By means of gentle suction the pipette is filled to the lower end of the capillary, which serves as the mark, the bottle lowered away, and the contents of the pipette are allowed to fall into a 100-c.c. conical flask containing 20 c.c. of 75% alcohol. Six drops of a 0.05% alcoholic phenolphthalein solution are now added and the whole titrated against $N/100$ sodium hydroxide solution. A permanent pale pink colour is taken as the end-point. A blank titration is made to allow for any acidity in the ether or alcohol. The construction of the pipette can be seen from the diagram. The tap E is three-way, one for suction, one for air inlet to allow the pipette to drain, and the third for compressed air, a blast of which, passing for 30 seconds, is found to cleanse the pipette adequately between each period of use. The upper tube of the pipette is of fairly wide bore capillary, partly for the sake of strength and also for quick filling. Any error in reading the meniscus level in this capillary will not therefore be very large.

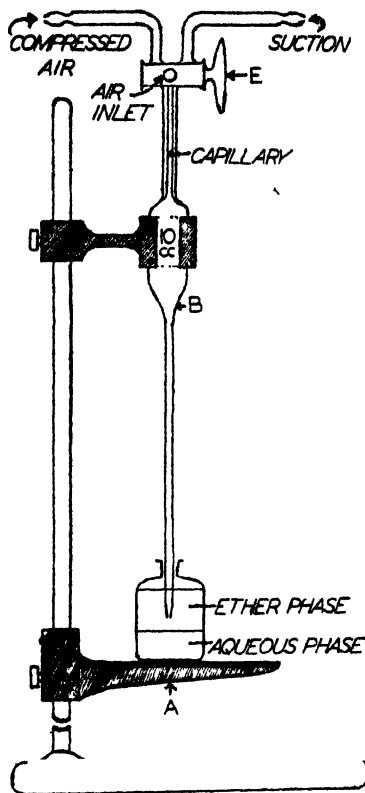


FIG. 1

Notes

1—The sulphuric acid solution is made up by allowing 500 c.c. of concentrated A.R. sulphuric acid (S.G. 1.84) to mix gradually with 500 c.c. of distilled water. The concentration of the acid should be about 19.5 N and 64.8% by weight.

2—The ether used is the ordinary commercial grade purified by the following method. Two litres of ether are shaken with 100 c.c. of N sodium hydroxide solution and 80 c.c. of N silver nitrate solution. The mixture is thoroughly agitated at frequent intervals for 24 hours and then separated, agitation being repeated with fresh lots of the silver nitrate-caustic soda mixture for 20 mins. and the ether again separated. It is now well washed with water several times and dried over potassium carbonate for 24 hours. It is finally allowed to stand over powdered sodium for 24 hours, and then fractionally distilled. It should distil between 34.5 and 35° C., and should give little or no colour with (a) Schiff's reagent (for acetaldehyde), (b) vanadic acid (for peroxides), or (c) desiccated copper sulphate (for water).

3—The $N/100$ caustic soda must be accurately made up by dilution of 10–15 N caustic soda solution, free from carbonate.

4—A short glass rod may be used in place of the rod stopper suggested. It can be grasped by a pair of forceps with fluted ends in order to stir the hydrolysis mixture and then be allowed to rest against the side of the weighing bottle when not in use.

5—The time required for the method is such that 12 determinations should be easily possible in one 8-hour day, provided that the drying and weighing have been done during the previous afternoon.

6—Smaller or larger quantities of acetylated cellulose than 0.5 gram may be taken for analysis, but it is advised not to use values of C_0 (see below) of less than 0.01 gram per litre and not to reduce the ratio of volume of sulphuric acid to weight of acetate below 10 c.c. of the former to 1 gram of material or complete dispersion may not occur.

(iii) Calculation of Results

Let W = dry weight of sample taken for analysis.

V = volume of liquid.

C = volume concentration of acetic acid.

Subscript $_0$ refers to liquid taken for extraction.

" $_1$ " ether phase at equilibrium.

" $_2$ " aqueous phase at equilibrium.

K = distribution coefficient at 20° C. of acetic acid between ether and aqueous sulphuric acid of the concentration employed (about 2*N*), each solvent being in equilibrium with the other; K is thus defined by the relation

$$K = C_2/C_1$$

and A = acetic acid yield of the substance.

Then

Weight of acetic acid in ether phase at equilibrium = C_1V_1

" " " aqueous " " = C_2V_2

∴ total weight of acetic acid in both phases = $C_1V_1 + C_2V_2$

which, since $K = C_2/C_1$, may be written $C_1V_1 + KC_1V_2$.

This amount was originally contained in the volume V_0 of liquid taken for extraction, whence

$$C_0 = \frac{C_1V_1 + KC_1V_2}{V_0} = C_1 \left(\frac{V_1 + KV_2}{V_0} \right)$$

Now V_1 , V_2 , and K are all unknown, but V_1 and V_2 may be held constant by taking constant volumes of ether and aqueous acid for extraction. We may, therefore, write $C_0 = aC$; hence, if the analytical procedure is standardised so that the same fraction of the original sample is always used for analysis, and the same fraction of the ether extract is always taken for titration with alkali of standard concentration, we may write

acetic acid yield, $A = fV/W$

where f is a constant of the analytical method,

V is the volume of alkali required to neutralise the acid in the sample of ether extract taken,

and W is the dry weight of the sample of acetylated cellulose taken.

(iv) Determination of the Analytical Constant f and Testing of the Method

Since the distribution coefficient of acetic acid between ether and aqueous sulphuric acid is not known accurately, and will probably vary with factors such as concentration and presence of other substances, it becomes necessary to determine the factor f in the equation $A = fV/W$ by a direct experimental method. This has been done for four substances—(a) acetic acid-sulphuric acid mixtures in which the sulphuric acid concentration is arranged to be the same as that at the end of an acetylated cellulose hydrolysis, (b) glucose penta-acetate prepared by the action of acetic anhydride on glucose in the presence of zinc chloride, (c) cellobiose octa-acetate prepared by the method of Haworth and Hirst,⁹ and (d) cellulose acetate rayon yarn acidified and extracted with ether to remove dressing and powdered by solution in acetone and precipitation with water.

The composition of the acetic acid solution was determined by titration, whilst the purity of the glucose penta-acetate and of the cellobiose octa-acetate was indicated by the sharpness of their melting points and their agreement with published figures, and was further checked by determining

the acetic acid yields by the methods of Ost¹⁷ and Barnett.¹ The composition of the acetylated cellulose was also determined by these latter methods. Results are recorded in Table I.

Table I

Weight of substance taken, <i>W</i> gram		Titre of 10 c.c. of ether extract, <i>V</i> c.c. <i>N</i> /100 NaOH		Analytical constant <i>f</i>
<i>Acetic Acid</i> —Varying quantities of <i>N</i> /10 acetic acid added to 5 c.c. of 64.8% sulphuric acid and the mixture diluted to 50 c.c. before extraction. Acetic acid yield = 100%.				
0.2604	...	20.54	...	1.268
0.2394	...	19.01	...	1.259
0.1794	...	14.00	...	1.281
0.1179	...	9.14	...	1.290
0.0497	...	4.54	...	1.315
0.0295	...	2.33	...	1.266
Mean				1.280
<i>Glucose Penta-acetate</i> —Acetic acid yield = 76.93%				
0.5000	...	30.13	...	1.277
0.4810	...	28.67	...	1.289
0.4380	...	26.43	...	1.276
0.4000	...	23.96	...	1.290
0.3000	...	18.05	...	1.278
0.2000	...	11.88	...	1.296
Mean				1.284
<i>Cellobiose Octa-acetate</i> —Acetic acid yield = 70.81%				
0.5000	...	27.55	...	1.285
0.4942	...	27.30	...	1.283
0.4000	...	21.90	...	1.294
0.3000	...	16.36	...	1.298
0.2000	...	10.86	...	1.303
Mean				1.292
<i>Acetylated Cellulose</i> —Acetic acid yield = 53.4%				
0.4813	...	20.12	...	1.277
0.4733	...	19.76	...	1.280
0.4540	...	18.85	...	1.287
0.4091	...	16.90	...	1.296
0.3850	...	16.08	...	1.278
0.1925	...	8.03	...	1.280
0.0963	...	4.03	...	1.275
Mean				1.282

It will be seen that the value of *f* is substantially constant from substance to substance. The mean value is 1.285.

(v) Treatment of Dyed Samples

Since most of the dyes used for acetylated cellulose are soluble in ether, it will in general be found necessary to strip samples of dyed acetate submitted for analysis by this method, since otherwise the dye may appear in the ether extract and obscure the colour of the indicator. Stripping may most conveniently be effected by shaking the dyed material with a mixture of 40–60 parts of methylene chloride and 60–40 parts of benzene. Usually, stripping is rapid and complete in the cold, but it may sometimes be necessary to give prolonged treatments under reflux. When the dye has been removed the

fabric is allowed to dry in the air, and should then be heated at 80° C. for 30 minutes to 1 hour to remove the last traces of the solvents. The structure of the fabric is not adversely affected by this treatment. Should the dye not be removed by this method it may be safely concluded that it will not interfere with the acetic acid determination. Many other stripping mixtures can be used, e.g. acetone and ether (45:55), followed by washing with ether, "methyl cellosolve" and ether, methylene chloride and ether, etc. Direct dyes are not removed by this treatment. Oils, fatty matter, gelatine, and so forth, which may be present, should, of course, be removed prior to analysis.

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20—SOME EXPERIMENTS ON CHLORINATION OF WOOL

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This paper is a record of the effects of the chlorination process applied under a wide variety of conditions, mainly from the practical standpoints of unshrinkability, strength, colour, handle, and level dyeing.

It is obviously impossible to find any one set of conditions which will produce the best results in all of these directions at once, *e.g.* a high degree of unshrinkability is almost inevitably accompanied by appreciable diminution in strength, and modification in handle.

The object was not to examine the purely theoretical aspect of the action of chlorine on wool, but to illustrate (1) the varying practical effects of applying a given percentage of "available" chlorine (as chlorine gas, "nascent" chlorine, or hypochlorous acid) under different conditions, notably in respect of the amount of acid used, and (2) the extreme importance of uniform application of the chlorinating medium, apart from its mode of preparation, and the condition of the fabric prior to its chlorination.

It will be clear that a given quantity of chlorine properly applied to give satisfactory unshrinkability without undue loss in strength and colour, can with improper application give poor unshrinkability with relatively serious loss in strength and colour.

The extremely rapid action of chlorine on wool is a serious obstacle to uniform application which remains the first essential to efficient processing, even when the most satisfactory chemical make-up of the bath has been ascertained for the required degree of treatment. The observations on relative levelness on subsequent dyeing are thus not only of direct interest, but provide some indication of the degree of uniformity of treatment resulting from the various modes of application employed.

Experiments were also made with a view to reducing this rapidity of action, including attempts to control the swelling of the wool fibres during the process, by addition of neutral salts, based on the observations recorded in W.I.R.A. Pub. No. 17, p. 15.

Experimental

The fabric used in the experiments was an uncarbonised, unmilled and neutral flannel, which showed on analysis 1.28% of total fat. It was used in preference to knitted web on account of its easier manipulation and measurement.

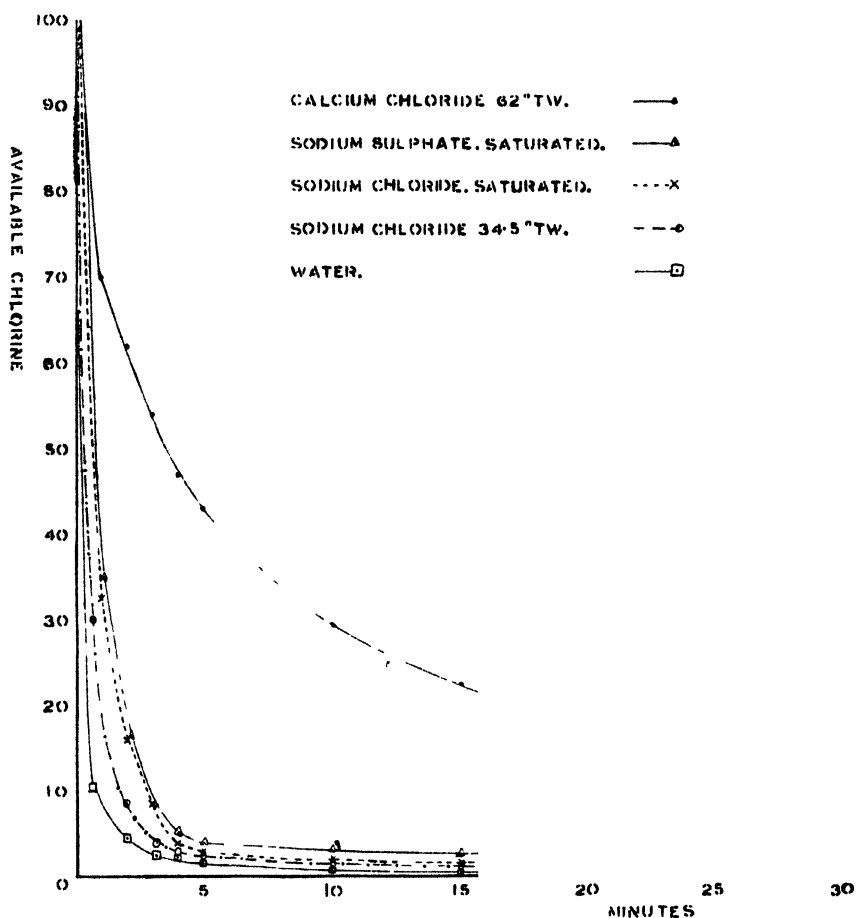
The patterns, approximately $15\frac{1}{2}$ in. \times 30 in., were adjusted in weight against a control 50-gram pattern, and the weight differences after processing similarly ascertained, thus obviating corrections for humidity changes. Each pattern was treated in a bath of 2,000 c.c. of the chlorinating liquor, *i.e.* 1 to 40. (In practice the proportion is usually between 1 part of fabric to 30, and 1 to 100 of liquor.)

Sources of Chlorine

The bleaching powder employed contained approximately 32% of available chlorine, and is designated B.P.

The chlorine gas employed was the ordinary commercial grade, from a chlorine cylinder. The quantities have been expressed in terms of the equivalent amount of B.P. for easier comparison. The hypochlorous acid was produced by passing chlorine into a suspension of calcium carbonate;

also by the action of boric acid on bleaching powder, and by treating bleaching powder with carbon dioxide. For the preparation of distilled hypochlorous acid, quantities in the proportion of 10 grams B.P., 19 grams boric acid, and 300 c.c. water were employed, the first 100 c.c. (or proportionate volume) of distillate being used for making up the bath.



GRAPH I

Chlorination of Patterns

The pattern, after thorough wetting out, was introduced into 2,000 c.c. of the chlorinating liquor and kept continuously moving, so as to obtain as level absorption as possible, for 30 mins. It was then well rinsed, treated with dilute bisulphite (1 part commercial liquor in 40 of water) again rinsed, neutralised with weak ammonia, gently scoured with potash olive soap, rinsed, and allowed to dry without stretching.

Preparation of the Bath

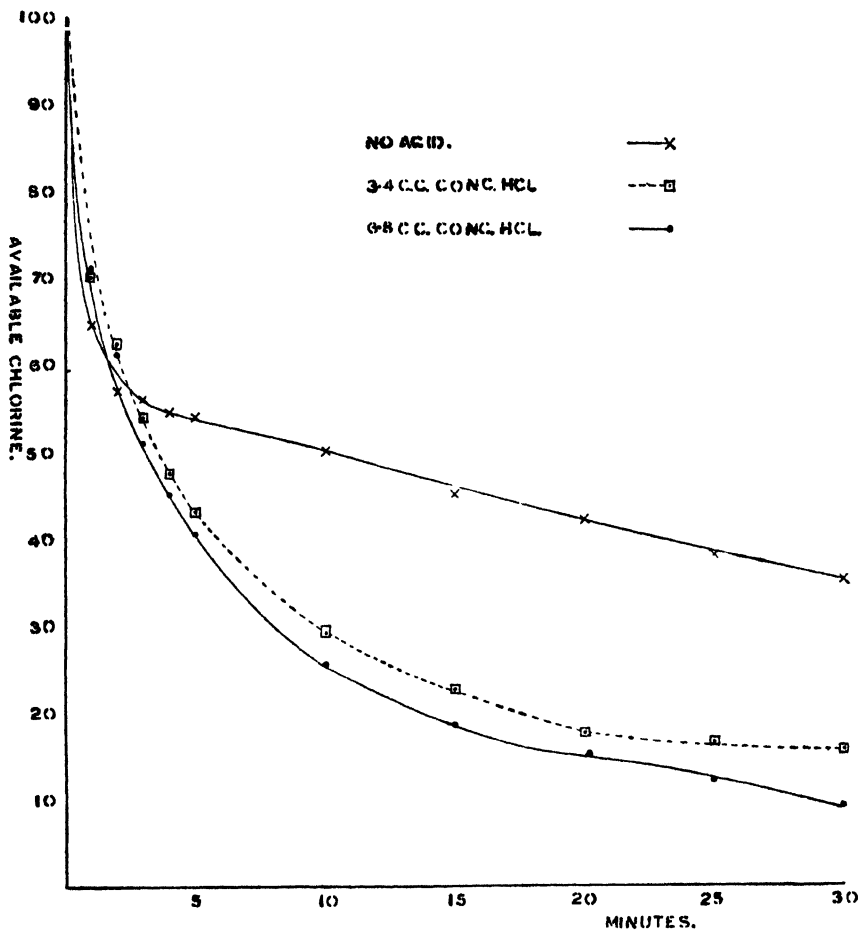
The reagent quantities are sufficiently indicated in the tables. For the chlorine experiments, the appropriate volume of chlorine water of known

strength was diluted with water to 2,000 c.c. In the case of salt solutions, the salts were dissolved and the solution decanted from sediment, if necessary, before adding the chlorinating reagents.

The solubility of chlorine in saturated common salt (36 grams NaCl per 100 c.c. water) at 20° C. is 0.34 grams per 100 c.c.

The strengths of calcium chloride employed were—

36° Tw. (sp. gr. 1.182)	20% CaCl_2 at 15° C.
46° Tw. (sp. gr. 1.233)	25%
62° Tw. (sp. gr. 1.301)	32%
Saturated CaCl_2	51% approx.



GRAPH II

Determination of Rate of Chlorine Absorption

These were not carried out on the main series of chlorinations, but in a series of special experiments. The appropriate bath having been prepared, at noted intervals from the time of introduction of the pattern, samples of the liquor were removed and the residual available chlorine determined by titration with potassium iodide and sodium thiosulphate. The results are shown in the graphs.

Comparative Shrinkage Test

After treating as described under "chlorination of patterns," p. T175, the batches of patterns with corresponding blanks were soaped in a 5% solution of equal parts soap flakes and potash olive soap, and hydro-extracted to leave them as nearly as possible equally moist. They were then milled in a pair of light stocks for $4\frac{1}{2}$ hours, with turning and replacing of the lengths at intervals, and afterwards washed out with warm water in a little ammonia, well rinsed, stretched taut by hand and allowed to dry slack. They were then measured for shrinkage in both directions, taking the mean of values at several positions, and the change in area calculated.

Strength and Elongation Tests

These were made on a Goodbrand machine on test pieces adjusted to standard width ($6\frac{1}{8}$ in.) after thorough conditioning in the humidity room. The shrinkage and strength figures in each lot should be compared with those for the corresponding blank given at the end of each group. The blanks, except where otherwise stated, were treated with bisulphite, ammonia, etc. precisely as with the chlorinated patterns.

Colour and Handle Test

The patterns were first roughly separated for degree of whiteness and handle, and finally arranged in three groups as judged by three observers. C1 (best), C2 and C3 for colour, and S (soft), M (medium), and H (harsh) for handle.

Levelness of Dyeing and Dyeing Affinity

The patterns were sewn end to end and dyed in a small piece-dyeing machine, with $1\frac{1}{2}$ % Erioglaucine Supra (Geigy), 3% acetic acid, and 10% Glauber salt. The order of level dyeing was judged visually and the patterns arranged into six groups, No. I being the most level. For the order of depth of shade it was found necessary to grade into seven groups, No. VII being the darkest. Within the range of each group, there was of course perceptible variation.

Discussion of Results

It is difficult to classify the results on any systematic basis, especially in view of the variety of effects to be considered. Some outstanding points may, however, be referred to. From the experiments without salt additions, the following abridged table brings out the effect of different acid additions, with the same quantity of bleaching powder.

Table I

B P Used	Acid Used	Area Change after Milling	Strength	Colour	Handle	Dyeing Levelness	Shade
2.5 gr.	3.6 c.c. HCl.	— 0.27%	72	C4	M	6	VI
2.5 gr.	6.8 c.c. HCl.	+ 2.29%	73	C1	S	6	VI
2.5 gr.	2.12 gm. boric	— 11.48%	83	C5	S	6	I
2.5 gr.	4.24 gm. boric	— 10.12%	84 (blank 91)	C4	S	6	I
2.5 gr.	2.25 c.c. acetic	— 0.12%	72 (blank 92)	C5	S	6	III

The boric acid treatment gave low unshrinkability and poor colour. Clearly the one using 6.8 c.c. HCl (S.G. 1.16) was the best of those giving high unshrinkability.

The effect of doubling the proportion of HCl with bleaching powder in different amounts, is shown in Table IIa below—

Table IIa

	Change in Area after Milling	Load lb.	Extension inches	Colour and Handle before Milling	Level Dyeing	Shade
0.8 gm. available chlorine 3.4 c.c. HCl	— 0.27%	72.0	2.92	C4.M	6	VI
1.6 " " " 6.7 "	+ 3.71%	66.7	2.58	C3.M	3	VII
3.2 " " " 13.4 "	+ 4.39%	64.3	2.46	C3.M	2	VII
0.8 " " " 6.8 "	+ 2.29%	73.3	2.46	C1.S	6	VI
1.6 " " " 13.4 "	+ 1.53%	76.3	2.58	C2.M	5	VII
3.2 " " " 26.8 "	+ 1.92%	66.0	2.17	C3.H	3	VII
Blank	—12.18%	87.7	3.79	C1.M	3	III

The larger amount of acid has practically no influence on unshrinkability and strength, but improves the colour with the smaller amounts of B.P.

The results in Table IIb, with modified treatment, show that with the lower percentages of B.P. there is an increased degree of unshrinkability with the higher proportions of acid, but the handle is less soft.

Table IIb

Cloth acidified first, wrung and immersed in B.P. for 30 mins. and re-immersed in the acid bath

	Change in Area after Milling	Load lb.	Extension inches	Colour and Handle before Milling	Level Dyeing	Shade
0.4 gm. available chlorine 1.7 c.c. HCl	—13.62%	92.0	3.58	C3.S	6	I
0.8 " " " 3.4 "	+ 0.26%	81.3	2.83	C3.S	6	III
1.6 " " " 6.7 "	+ 3.71%	83.3	2.71	C3.S	6	III
0.4 " " " 3.4 "	— 4.46%	85.3	3.25	C3.M	6	III
0.8 " " " 6.7 "	— 4.19%	80.7	2.88	C3.M	5	VI
1.6 " " " 13.4 "	+ 3.08%	82.7	2.46	C3.M	6	V
Blank	—	98.7	2.54	—	—	II

Table IIc shows the comparative effects of boracic and acetic acids in more detail.

Table IIc

	Change in Area after Milling	Load lb.	Extension inches	Colour and Handle before Milling	Level Dyeing	Shade
0.8 gm. avail. chlorine 2.12 gm. boracic acid	—11.48%	83.7	3.58	C5.S	6	I
1.6 " " " 4.25 " "	— 1.54%	72.3	2.71	C6.S	3	I
3.2 " " " 8.50 " "	+ 2.66%	62.7	2.62	C7.S	6	lt. green
Blank	—15.8 %	91.3	3.71	C2.S	5	III
0.8 gm. avail. chlorine 4.24 gm. boracic acid	—10.12%	84.7	3.42	C4.S	6	I
1.6 " " " 8.5 " "	+ 0.92%	71.3	2.67	C6.S	6	I
3.2 " " " 17.0 " "	+ 5.01%	64.0	2.92	C7.S	5	lt. green
0.8 " " " 2.25 c.c. acetic acid	— 0.12%	72.0	3.29	C5.S	6	III
1.6 " " " 4.5 " "	+ 4.42%	74.7	2.96	C5.M	3	V
3.2 " " " 9.0 " "	+10.31%	78.7	2.87	C6.H	4	V
Blank	—14.10%	92.0	3.87	C3.S	4	III

In every case the colour is poor and with boracic acid the affinity for dye is small. Unshrinkability with boracic acid is decidedly less than with HCl. Acetic acid, however, gives good unshrinkability and affinity for dye, but inferior to those given by HCl.

The following table shows the comparative effect of hypochlorous acid.

Table II

	Change in Area after Milling	Load lb.	Extension inches	Colour and Handle before Milling	Level Dyeing	Shade
10 gm. B.P. equivalent to 3.2 gm. Available chlorine plus CO ₂	+ 4.28%	69.0	2.92	C6	5	med. green
HOCl obtained from 10gm. B.P. and 17 gm. boric acid	+ 2.97%	72.0	2.50	C5.S	3	lt. green
HOCl by CaCO ₃ = 0.5% Cl ₂	-15.85%	117.7	4.12	C1.M	—	II
" " = 0.923% Cl ₂	- 8.21%	103.3	3.58	C2.M	—	II
" " = 1.50% Cl ₂	- 5.08%	87.3	3.17	C4.M	—	III
" " = 3.07% Cl ₂	+ 4.56%	84.0	3.00	C4.M	—	IV

Hypochlorous acid appears to give less unshrinkability than equivalent amounts of B.P. and the colour is inferior to that with B.P. and HCl.

Addition of neutral salts gave somewhat anomalous results, though in acidified solutions, common salt and HCl gave all-round results superior to sodium sulphate and sulphuric acid. (See Tables III and IV.)

Table III
Effect of Saturating with Glauber's Salt

	Change in Area after Milling	Load lb.	Extension inches	Colour and Handle before Milling	Level Dyeing	Shade
0.8 gm. available chlorine 3.4 c.c. HCl ...	- 0.14%	81.5	3.96	C3.S	5	IV
1.6 " " " 6.7 " ...	+ 4.68%	89.5	2.81	C2.S	5	VI
3.2 " " " 13.4 " ...	+ 3.11%	85.5	2.50	C3.M	1	VII
0.8 " " " 6.8 " ...	- 3.24%	86.7	3.125	C4.S	6	IV
1.6 " " " 13.4 " ...	+ 3.26%	84.3	2.96	C6.S	3	V
3.2 " " " 26.8 " ...	+ 3.24%	79.6	2.54	C5.S	2	VII
Blank	-16.25%	93.7	3.87	C1.S	5	III

Colour and handle effects are slightly superior to those without salt addition with the smaller quantities of acid, but suffer in comparison when the quantity of acid is doubled. The strength and level dyeing are generally improved with equal unshrinkability compared with the treatment with acid alone.

Table IV
Effect of Saturating with Common Salt

	Change in Area after Milling	Load lb.	Extension inches	Colour and Handle before Milling	Level Dyeing	Shade
0.8 gm. available chlorine 3.4 c.c. HCl ...	+ 3.31%	80.0	2.96	C3.S	3	VII
1.6 " " " 6.7 " ...	+ 3.29%	73.3	2.21	C3.M	2	VII
3.2 " " " 13.4 " ...	+ 2.21%	70.7	1.87	C2.M	2	VII
0.8 " " " 6.8 " ...	+ 0.18%	85.0	3.125	C1.S	4	VII
1.6 " " " 13.4 " ...	+ 1.57%	74.7	2.71	C1.M	3	VII
3.2 " " " 26.8 " ...	+ 2.19%	71.3	2.125	C2.H	1	VII
Blank	-16.25%	93.7	3.87	C1.S	5	III
0.8 gm. avail. chlorine 2.5 gm. boric acid ...	+ 4.03%	72.3	3.29	C5.S	4	IV
1.6 " " " 4.25 " " ...	+ 4.41%	82.7	3.17	C6.S	2	V
3.2 " " " 8.5 " " ...	+ 2.24%	74.7	2.62	C7.S	4	med. green
Blank	-15.88%	91.3	3.71	C2.S	5	III
10 gm. B.P. equivalent to 3.2 gm. available chlorine + CO ₂	+ 1.85%	78.7	2.54	—	3	V
HOCl distilled from 10 gm. B.P.	-15.46%	97.7	3.25	C1.S	6	III

Using HCl, unshrinkability, strength, and level dyeing appear to be better than without addition of salt; and generally there is an improvement in colour and handle. With boracic acid, unshrinkability and level dyeing are improved, there is, however, no improvement in colour. With hypochlorous acid, unshrinkability is again unsatisfactory.

Obviously higher percentages of available chlorine can be applied in salt solutions without undue loss in strength. Saturated calcium chloride solutions tend to inhibit the "unshrinkable" action of B.P., even in presence of acid, except with high proportions of B.P., as shown in Tables V and VI.

Table V
Effect of Saturating with Calcium Chloride

		Change in Area after Milling	Load lb.	Exten- sion inches	Colour and Handle before Milling	Level Dyeing	Shade
0.4 gm. available chlorine	1.7 c.c. HCl	...	...	...	...	...	III
0.8 "	" "	...	...	...	...	...	III
1.6 "	" "	...	...	...	...	...	III
Blank	...	...	...	...	...	...	...

Table VI
Saturated Calcium Chloride in Comparison of Various Acidified and Unacidified B.P. Solutions

		Change in Area after Milling	Load lb.	Exten- sion inches	Colour and Handle before Milling	Level Dyeing	Shade
0.93 gm. available chlorine.	No acid	...	...	...	...	...	II
0.93 "	" "	...	...	...	...	...	III
0.93 "	" "	...	...	...	...	...	III
2.66 "	" "	...	...	...	...	...	II
2.66 "	" "	...	...	...	...	...	IV
0.93 "	" "	...	...	...	...	...	II
Blank	...	...	...	...	...	...	III

These results are generally similar to those in Table V, suggesting that a saturated solution of calcium chloride is not so satisfactory as common salt or Glauber's salt. More dilute solutions were, therefore, tried and the results are given in Table VII.

A number of interesting results are shown in this table. CaCl_2 60° Tw. and 1.07 gm. available chlorine gives excellent colour and handle and a good value for strength. The same may be said of 50° Tw. CaCl_2 and 1.07 gm. available chlorine acidified with 7.9 c.c. HCl, also 30° Tw. CaCl_2 and 1.07 gm. available chlorine acidified with 15.8 c.c. HCl, and the strength is well maintained. But larger amounts of B.P. are required to give the same amount of unshrinkability as when no salt addition is made. In practice, however, a limited amount of unshrinkability is permitted, and the general improvement in colour and handle obtained with salt solutions is worth noting. Generally, though the results are not all consistent, either as to felting or loss of strength, the calcium chloride results give the impression that greater strength is retained for a given degree of unshrinkability.

Table VII
Comparative Effects of Varying Concentrations of Calcium Chloride
in the Bath

	Change in Area after Milling	Load lb.	Exten- sion inches	Colour and Handle before Milling	Level Dyeing	Shade
CaCl ₂ 82° Tw. 1.6 gm. avail. chlorine 5.9 c.c. HCl	— 7.97%	109.0	3.42	C3.M	—	III
" 66° " " " "	— 8.87%	106.0	3.12	C4.M	—	III
" 46° " " " "	+ 2.60%	96.0	2.87	C4.M	—	III
" 36° " " " "	— 6.09%	85.3	3.12	C3.S	—	IV
No. CaCl ₂	+ 0.00%	92.0	2.92	C1.S	—	IV
Blank	— 18.10%	118.0	3.67	blank	—	III
CaCl ₂ 59.5° Tw. 2.5 gm. EIB. 11.8 c.c. HCl	— 1.04%	90.3	2.21	C3.M	—	IV
" 60° Tw. 1.6 gm. avail. chlorine 11.8 c.c. HCl	+ 1.01%	84.7	2.125	C1.S	—	—
" " 1.6 " " " "	+ 1.03%	95.3	2.25	C1.S	—	—
" " 1.07 " " " "	— 3.49%	103.7	2.50	C1.S	—	—
" " 1.07 " " " "	— 1.98%	93.2	2.25	C1.M	—	—
" 50° Tw. 1.6 " " " "	— 0.46%	111.3	2.875	C4.M	—	—
" " 1.6 " " " "	— 3.04%	83.3	2.33	C1.M	—	—
" " 1.6 " " " "	— 0.00%	92.3	2.33	C1.H	—	—
" " 1.07 " " " "	— 9.28%	104.0	3.00	C3.S	—	—
" " 1.07 " " " "	— 1.02%	104.3	2.75	C1.S	—	—
" " 1.07 " " " "	— 0.57%	107.3	2.625	C1.M	—	—
" 40° Tw. 1.6 " " " "	— 1.01%	90.0	2.92	C4.M	—	—
" " 1.6 " " " "	+ 0.43%	98.0	2.54	C2.M	—	—
" " 1.6 " " " "	— 2.04%	93.0	2.43	C2.H	—	—
" " 1.07 " " " "	— 3.54%	95.7	2.75	C3.S	—	—
" " 1.07 " " " "	— 1.55%	104.0	2.75	C2.M	—	—
" " 1.07 " " " "	— 0.57%	92.3	3.00	C2.M	—	—
" " 0.53 " " " "	— 15.94%	114.3	3.33	C3.S	—	—
" " 0.53 " " " "	— 3.99%	94.3	3.875	C2.S	—	—
" " 0.53 " " " "	— 16.19%	103.0	3.375	C2.S	—	—
" 30° Tw. 1.07 " " " "	— 7.59%	97.3	2.83	C1.S	—	—
" " 1.07 " " " "	— 1.04%	90.7	3.125	C1.S	—	—
" " 0.53 " " " "	— 5.83%	89.0	3.21	C2.M	—	—
" " 0.53 " " " "	— 8.45%	93.3	3.25	C1.S	—	—
" 20° Tw. 1.07 " " " "	— 6.94%	97.0	2.96	C1.S	—	—
" " 1.07 " " " "	— 5.50%	98.7	2.96	C1.S	—	—
" " 0.53 " " " "	— 7.98%	100.0	3.00	C1.S	—	—
" " 0.53 " " " "	— 11.65%	98.3	3.04	C1.S	—	—
Water 1.07 " " " "	— 5.02%	99.7	2.75	C1.M	—	—
" 1.07 " " " "	— 2.52%	97.0	2.75	C2.M	—	—
" 0.53 " " " "	— 8.07%	98.0	3.17	C1.S	—	—
" 0.53 " " " "	— 9.88%	98.0	2.875	C2.M	—	—
Blank	— 17.65%	124.3	3.54	S	—	—

Chlorine water, either alone or in acidified solution, appears to give the best effect when used in quantity equivalent to 2.5 gm. of B.P. as shown in Table VIII.

Table VIIIa
Chlorine Water alone

	Change in Area after Milling	Load lb.	Exten- sion inches	Colour and Handle before Milling	Level Dyeing	Shade
3.2 gm. avail. chlorine equiv. to 10 gm. B.P.	+ 1.26%	80.7	2.54	C3.M	1	VII
1.6 " " " " "	+ 2.93%	76.0	2.54	C3.M	4	VII
0.8 " " " " "	— 0.38%	81.3	2.63	C2.M	5	VI
0.4 " " " " "	— 8.44%	80.7	3.25	C1.M	6	IV
0.2 " " " " "	— 12.18%	91.0	3.63	—	4	III
0.1 " " " " "	— 16.30%	97.3	3.63	C2.S	5	III
Blank	— 17.64%	96.0	3.83	C2.S	4	III

The strength of the treated patterns is good and unshrinkability is generally similar to treatment with equivalent amounts of B.P. and HCl.

(See Table I.) On the whole, the colour and handle is in favour of chlorine alone. Level dyeing properties improve with increased amount of chlorine; this follows as a consequence of the extremely rapid absorption of chlorine by wool.

Table VIIIb
Chlorine Dissolved in Saturated Solution of Common Salt

	Change in Area after Milling	Load lb.	Extension inches	Colour and Handle before Milling	Level Dyeing	Shade
3.2 gm. avail. chlorine equiv. to 10 gm. B.P.	+ 3.43%	70.0	2.04	C2.S	3	VII
1.6 " " " " 5 "	+ 3.01%	77.7	2.46	C3.M	2	VII
0.8 " " " " 2.5 "	+ 1.58%	75.3	2.75	C3.S	4	VII
0.4 " " " " 1.25 "	- 1.76%	77.0	2.96	C3.S	4	VI
0.2 " " " " 0.625 "	-10.29%	90.0	3.46	C3.S	4	IV
Blank	-17.64%	96.0	3.83	C2.S	4	III
3.2 gm. avail. chlorine equiv. to—						
10 gm. B.P. +10 c.c. HCl	+ 3.76%	78.7	2.17	C1.H	—	VII
1.6 " " " " 5.0 "	- 0.07%	90.3	2.79	—	—	VII
0.8 " " " " 2.5 "	- 2.38%	86.3	2.71	—	—	VII
0.4 " " " " 1.25 "	- 4.13%	88.7	3.00	—	5	VI
0.2 " " " " 0.625 "	-11.69%	88.7	3.04	—	—	V
Blank	-28.60%	87.3	3.17	C3.S	—	—

Table VIIIc
Chlorine Dissolved in Saturated Solution of Sodium Sulphate

	Change in Area after Milling	Load lb.	Extension inches	Colour and Handle before Milling	Level Dyeing	Shade
3.2 gm. avail. chlorine equiv. to 10 gm. B.P.	+ 5.80%	92.0	2.71	—	1	VII
1.6 " " " " 5 "	+ 5.44%	78.7	2.29	—	3	VII
0.8 " " " " 2.5 "	+ 0.22%	71.0	3.17	C2.S	5	V
0.4 " " " " 1.25 "	-11.32%	81.0	3.21	C3.S	6	III
0.2 " " " " 0.625 "	-14.71%	92.0	3.42	C3.S	6	III
3.2 " " " " 10 gm. B.P.						
+ H ₂ SO ₄	+ 3.64%	80.0	2.33	C2.M	1	VII
1.6 " " " " 5 "	+ 4.74%	85.7	2.54	C3.S	4	VII
0.8 " " " " 2.5 "	+ 1.20%	82.7	2.75	—	6	VI
0.4 " " " " 1.25 "	- 6.50%	80.3	2.92	C2.S	5	IV
0.2 " " " " 0.625 "	-10.90%	83.0	3.29	C2.S	4	III
Blank	-28.60%	87.3	3.17	C3.S	—	—

Table VIId
Chlorine Dissolved in Saturated Solution of Calcium Chloride

	Change in Area after Milling	Load lb.	Extension inches	Colour and Handle before Milling	Level Dyeing	Shade
0.4 gm. avail. chlorine equiv. to 1.25 gm. B.P.	-16.48%	92.0	4.12	C3.S	—	III
0.8 " " " " 2.5 "	- 4.59%	80.7	2.75	C3.S	—	III
1.6 " " " " 5.0 "	- 0.18%	75.7	2.67	C3.S	—	IV
Blank	-21.11%	96.0	4.33	C2.S	—	III

A survey of the results in this table shows that chlorine in saturated sodium sulphate gives the best values for strength, whilst there is very little difference in colour and handle between any of the treatments. The calcium chloride results show the least unshrinkability and are inferior in strength.

Table IX

Showing the Influence of Temperature on the Action of Bleaching Powder and HCl in Aqueous Solution

	Change in Area after Milling	Load lb.	Extension inches	Colour and Handle before Milling	Level Dyeing	Shade
Ice and 0.93 gm. avail. chlorine 4 c.c. HCl	- 0.86%	90.3	2.79	C4.S	—	IV
17° C. " " " " "	- 0.17%	92.7	3.00	C1.M	—	III
32° C. " " " " "	- 3.16%	89.3	3.33	C1.S	—	IV
45° C. " " " " "	- 5.13%	86.3	3.25	C3.S	—	IV
Ice " " " 8 c.c. "	+ 2.58%	94.7	2.87	C1.S	—	IV
17° C. " " " " "	- 0.11%	94.7	3.00	C1.S	—	IV
32° C. " " " " "	- 2.13%	92.0	3.25	C1.S	—	IV
45° C. " " " " "	- 1.15%	92.0	3.08	C1.S	—	IV

The most satisfactory results are obtained at ordinary temperatures and no advantage is gained by the use of ice.

Table X
Exceptional Methods for Comparison

	Change in Area after Milling	Load lb.	Extension inches	Colour and Handle before Milling	Level Dyeing	Shade
10 gm. potassium permanganate ...	-18.2%	95.7	3.65	C3.S	2	III
3.2 gm. avail. chlorine as B.P. plus sodium carbonate. Settle and add 17 gm. boric acid	+ 3.01%	79.0	2.79	C5.S	4	lt. green
Bleaching powder without addition, 10 gm. (equiv. to 3.2 gm. Cl ₂) ...	- 4.75%	52.3	2.79	C1.S	5	II
5.5 c.c. H ₂ O ₂ 30% equiv. to 10 gm. B.P. avail. chlorine 3.2 gm. ...	-20.89%	99.0	3.46	—	—	III
Potassium permanganate and HCl in saturated NaCl at 40° C. ...	+ 2.00%	69.0	2.21	C4.H	—	IV
Alcohol with 2.5 gm. E.I.B., 7.1 c.c. HCl (electro bleach 80% avail. chlorine) ...	- 3.58%	90.0	2.46	C2.M	—	IV
Blank ...	-28.60%	87.3	3.17	C3.S	—	—
Flannel absolutely untreated ...	—	110.7	2.62	—	—	—

The above treatments do not call for further comment.

Table XI

Comparison of Various Salt Additions and Variation of Acid using smaller quantities of Bleaching Powder

	Change in Area after Milling	Load lb.	Extension inches	Colour and Handle before Milling	Level Dyeing	Shade
No salt 0.25 gm. avail. chlorine 1.13 c.c. HCl	-14.79%	98.0	3.75	C3.M	—	III
" " " " 2.26 "	-11.15%	91.0	3.58	C2.S	—	III
NaCl " " " 1.13 "	-15.01%	95.3	3.92	C2.S	—	III
" " " " 2.26 "	-13.81%	87.7	3.50	C4.S	—	III
CaCl ₂ " " " 1.13 "	-24.98%	111.3	3.96	C4.S	—	I
" " " " 2.26 "	-27.49%	115.0	4.33	C3.M	—	II
No salt 0.15 gm. " 12 gm. conc. H ₂ SO ₄ in 5,000 c.c. water	-30.45%	112.7	4.12	C4.M	—	III
" 1.28 gm. " 6 gm. conc. H ₂ SO ₄ in 5,000 c.c. water	+ 6.70%	75.0	2.62	C2.S	—	IV

The trials given in this table were made to compare the results of milder chlorination.

Discussion of Graphs

Graph I shows that accompanying the known depression of swelling, the rate of chlorine absorption is slowed down considerably. In the first two minutes 96% absorption takes place in aqueous medium, 91% in brine of 34.5° Tw., 84% in saturated brine and 84% in saturated Glauber salt solution. There should thus be a considerable smoothing down of the action on the fabric. This is borne out for example by the relative levelness of dyeing obtained with 5 gm. B.P., equivalent to 1.6 gm. available chlorine on 50 gm. cloth in water, saturated common salt and saturated Glauber's salt respectively which, as inspection of the tables will show, are assigned to Grades 4, 2, and 3 respectively.

The very marked retardation with saturated calcium chloride in which, as observed above, the degree of unshrinkability produced by a given percentage of chlorine is greatly reduced, suggested that while repression of swelling, by retarding the rate of absorption, may favour more level action, undue repression of swelling confines the action to the surface, and prevents penetration of the chlorine to the cortex, which appears essential to the destruction of the felting property. Graph II indicates, in line with the practical results, that the absorption is smoother in presence of acid and more complete with the heavier proportion of acid.

CORRIGENDUM

**"7—REPORT TO THE NEW ZEALAND GOVERNMENT ON
ENGLISH LEICESTER (38's/42's), ROMNEY (44's/46's), ROMNEY
(46's/48's), AND CORRIEDALE (50's/56's) WOOLS"**

By ALDRED F. BARKER, M.Sc., F.T.I.

The following corrections should be noted—

On page 169—"Schlumberger Top Analysis for Length" read "46's Romney" as "48's Romney," and "48's Romney" as "46's Romney."

On page 170, Fig. 2—Transpose 46's and 48's Romney. Curves in accordance with the analysis given on page 169.

THE JOURNAL OF THE TEXTILE INSTITUTE TRANSACTIONS

21—THE DETERMINATION OF THE HYDROGEN ION CONCENTRATION OF HYPOCHLORITE SOLUTIONS WITH THE GLASS ELECTRODE

(a) THE DISSOCIATION CONSTANT OF HYPOCHLOROUS ACID

(b) THE pH VARIATIONS OF HYPOCHLORITE SOLUTIONS DURING THE BLEACHING OF COTTON

By GEORGE FORREST DAVIDSON, B.Sc.
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- IV—The Dissociation Constant of Hypochlorous Acid.
- V—The Variation of the Hydrogen Ion Concentration of Hypochlorite Solutions during the Bleaching of Cotton.
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 - (6) The Effect of the Consumption of Hypochlorite on the pH of Hypochlorite Solutions.
 - (7) General Discussion.

I—INTRODUCTION AND SUMMARY

The importance of the hydrogen ion concentration of the hypochlorite solutions used in the bleaching of cellulosic materials has been increasingly recognised in recent years. In bleaching such materials, it is desired to destroy the colouring matters with the minimum oxidation of the cellulose, and it is important to discover the best conditions for achieving this end and to control the pH accordingly. Clibbens and Ridge,³ by working with solutions buffered at various pH values, showed that the maximum rate of oxidation of cellulose by hypochlorites occurs at about pH 7, and their results have been confirmed by Kaufmann.^{1,2} Although the importance of the pH of hypochlorite bleach liquors has thus been recognised, none of the older methods of pH measurement can be used as a means of control. The use of the hydrogen and quinhydrone electrodes is excluded by the oxidising action of hypochlorites, whilst the colorimetric method is rendered inapplicable by the rapid bleaching of the indicators. The present paper describes the application of the glass electrode to the determination of the pH of hypochlorite solutions, and records the results of determinations of the dissociation constant of hypochlorous acid, and of investigations on bleach liquors, made with its help.

The measurement of the glass electrode *E.M.F.* was made by means of a portable valve electrometer designed by Harrison¹¹ for industrial use, with which it is possible to determine the *pH* of a solution with an accuracy of ± 0.02 unit in a few minutes. The glass electrode used, and its calibration by means of standard buffer solutions, are described.

It is shown that the presence of hypochlorites does not interfere with the determination of hydrogen ion concentration by means of the glass electrode. With the help of this electrode, the dissociation constant of hypochlorous acid has been determined by electrometric titrations of sodium and calcium hypochlorite solutions, and found to be 3.7×10^{-8} at $18^\circ - 20^\circ$ C. This value is in agreement with that of Sand¹⁹ (3.7×10^{-8}) obtained by another method, and indicates that the value found by Noyes and Wilson¹⁸ (6.7×10^{-10}) is erroneous.

Experimental bleaches have been carried out on a cloth boiled with soda ash (commercial sodium carbonate), using as bleaching agent (a) calcium hypochlorite, (b) sodium hypochlorite, and (c) sodium hypochlorite buffered at a high *pH* by the addition of soda ash, and the variation of the *pH* during the bleaches has been followed with the glass electrode. When calcium or sodium hypochlorite is used, the *pH* falls very rapidly during the early stages of the bleach, and during $2\frac{1}{2}$ hours' bleaching it sinks to a value in the neighbourhood of 8. If the partially spent liquor from a bleach is used in making up the bleach liquor for the next bleach, the spent liquor exerts a buffer action and reduces the initial *pH* of the bleach liquor made up with it. The fall in *pH* during bleaching with such a solution is more gradual, but the final *pH* values attained are lower than in the first bleach of a series. The fall in *pH* during bleaching is greater with calcium hypochlorite than with sodium hypochlorite, probably due partly to the lower free alkalinity of calcium hypochlorite solutions and partly to the precipitation of calcium carbonate which is only slowly redissolved as the *pH* falls, and thus does not exert its maximum buffer action. When soda ash is added to a sodium hypochlorite liquor, the buffer action of the carbonate-bicarbonate system prevents a rapid fall of *pH* during bleaching, and after $2\frac{1}{2}$ hours the *pH* is still above 10.

When a partially spent bleach liquor is kept, the concentration of available chlorine decreases rather rapidly, and this is shown to be probably due to the oxidation of organic matter derived from the cloth during the bleaching process. This decrease in concentration is accompanied by a decrease in *pH*.

By electrometric titration of completely spent bleach liquors, it is shown that the buffer action of the latter is due to the presence of carbonic acid, but the titration curves also indicate the presence of some weak acid or acids stronger than carbonic acid. Experiments in which bleach liquors were circulated in the bleaching apparatus in the absence of cloth, have shown that atmospheric carbon dioxide plays only a minor part in the reduction of the *pH*, so that the carbonic acid present in the spent liquors is mainly produced during bleaching. A small amount of precipitate found in calcium hypochlorite spent liquors gave the reactions of calcium oxalate, so that it is probable that oxalic acid is an intermediate product in the process of carbon dioxide formation.

The effect on the *pH* of a hypochlorite bleach liquor of the consumption of the hypochlorite in oxidation processes, as distinct from the effect of acidic products of the oxidation, is discussed from the theoretical standpoint, and the theoretical conclusions are confirmed by the results obtained by electrometric titration of hypochlorite solutions of various initial *pH* values with

hydrogen peroxide solutions. For the consumption of a given fraction of the available chlorine, the effect on the pH is the greater the lower the initial pH . Thus, whilst the rapid fall of the pH in the early stages of bleaching is due to the production of carbonic and other acids, in the later stages the consumption of the hypochlorite also contributes to the fall. The action of the hypochlorite and carbonate buffer systems during bleaching and during the storage of partially spent liquors is discussed, and an observed rise in pH of completely spent sodium hypochlorite liquors when exposed to the air is explained by loss of carbon dioxide and a consequent readjustment of the carbonate equilibrium in the solution.

II—THE USE OF THE GLASS ELECTRODE

(1) Description of Apparatus

The use of the glass electrode depends on the fact that when two solutions of different pH are separated by a thin membrane of suitable glass, a potential difference is set up across the membrane which is proportional to the difference in pH . The measurement of this potential difference presents some difficulty, owing to the very high resistance of the glass membrane, which precludes the use of the usual potentiometric method with a galvanometer as null instrument. Sensitive electrometers such as the Compton and Lindemann types have been used, but the recent development of the electrometer valve has provided a new method of measuring glass electrode *E.M.F.*'s which combines simplicity and rapidity. The method employed in the present work is that due to Harrison,¹¹ in which this type of valve is used. The apparatus was a portable outfit supplied by Messrs. Baird & Tatlock (London) Ltd., which incorporates Harrison's circuit. The galvanometer used is of the pointer type, as the apparatus was designed for works use, and the sensitivity of the apparatus is limited by the sensitivity of this galvanometer. The accuracy obtainable in the measurement of an *E.M.F.* with this outfit is ± 1 millivolt, corresponding to less than ± 0.02 pH unit, which is sufficient for the present purpose.

The glass electrodes employed were of the type described by Hughes,¹² consisting of a thin bulb blown on the end of a piece of glass tubing, with a small calomel electrode fitting inside this tube and dipping into *N/10* hydrochloric acid contained in the bulb and tube. The bulb was protected by four legs of thin glass rod fused on to the neck of the electrode and bent so as to form a guard round the bulb. The tubing and bulb were of special glass made according to the formula of Morton quoted by Harrison.¹¹ The tubing had a diameter of 10 mm., and the diameter of the bulb which constituted the glass membrane was about 15 mm. It was found necessary to make a number of electrodes, and select those which proved suitable for use. Such electrodes had a D.C. resistance of from 20 to 60 megohms. To make a measurement of the pH of a solution, the glass electrode was clamped so that the bulb was immersed in the solution, and electrical connection to the solution made by means of a saturated calomel half-cell. In order to prevent diffusion of the potassium chloride into the test solution, the end of the side tube of the calomel half-cell that dipped into this solution was bent upwards and closed by a plug which was a ground fit, but ungreased. The *E.M.F.* measured was thus that of the cell



All the measurements recorded were made at room temperature.

(2) Calibration of the Electrode

Various investigators^{5, 12, 15, 16} have shown that when a glass electrode with a solution of definite pH inside it is put in solutions of various pH values, the observed $E.M.F.$ is the same linear function of the pH of the outside solution no matter what cations are present, so long as the pH lies between about 1 and about 9.5; above pH 9.5, the relation between $E.M.F.$ and pH depends on the cations present. The electrode may therefore be calibrated by measuring the $E.M.F.$ when it is placed in a series of buffer solutions of known pH . As determinations of the pH of sodium and calcium hypochlorite solutions were required, it was necessary to calibrate the electrode in the region above pH 9.5 in the presence of sodium and calcium ions respectively. Fig. 1

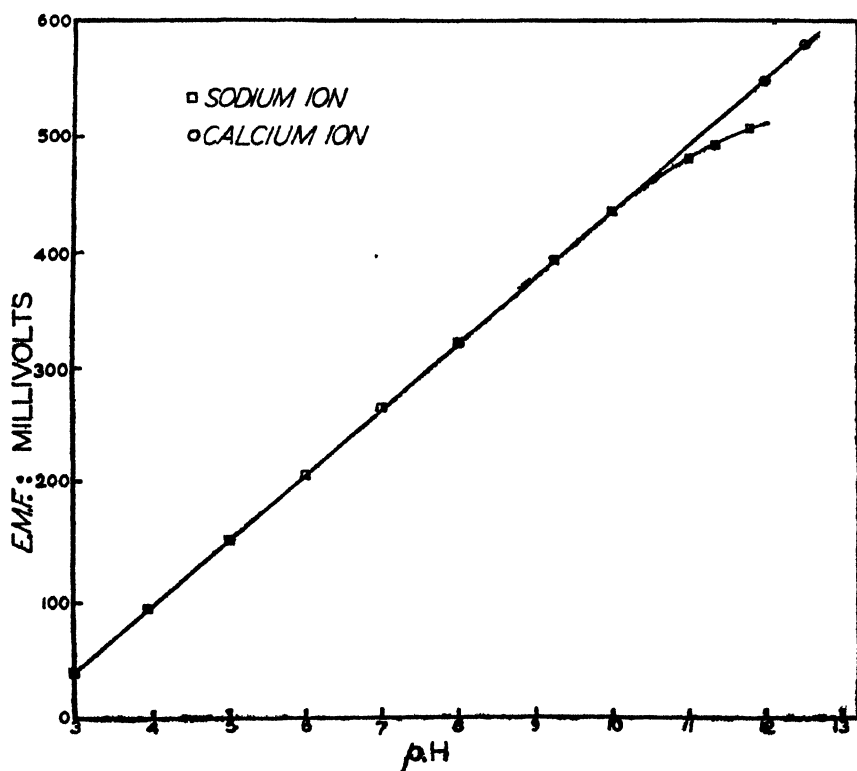


FIG. 1

shows a typical calibration curve for pH values up to 9.24, with extensions above this pH for solutions containing these cations; the composition of the various standard buffer solutions and the $E.M.F.$'s observed with a particular electrode in them are given in Table 1. The figure shows that the relation between $E.M.F.$ and pH is linear up to very nearly pH 10. Above this pH , when sodium ions are present, the $E.M.F.$ increases less rapidly than corresponds to the linear relation, in agreement with the results of other workers.^{5, 12, 15, 16} MacInnes and Belcher¹⁵ have shown that when the only metallic ions present are those of calcium, there is no appreciable deviation from the linear relation at high pH values, and this is confirmed by the results shown in Fig. 1.

Table I

Solution	Reference	pH	Glass Electrode <i>E.M.F.</i> (millivolts)
25 c.c. <i>M</i> /5 potassium hydrogen phthalate + 20.4 c.c. <i>M</i> /10 HCl, diluted to 100 c.c.	Clark and Lubs, cf. Clark ²	3.00	39
<i>M</i> /20 potassium hydrogen phthalate	" "	3.97	94
25 c.c. <i>M</i> /5 potassium hydrogen phthalate + 23.65 c.c. <i>M</i> /10 HCl, diluted to 100 c.c.	" "	5.00	153
25 c.c. <i>M</i> /5 KH_2PO_4 + 5.64 c.c. <i>M</i> /10 NaOH, diluted to 100 c.c.	" "	6.00	209
25 c.c. <i>M</i> /5 KH_2PO_4 + 29.54 c.c. <i>M</i> /10 NaOH, diluted to 100 c.c.	" "	7.00	267
25 c.c. <i>M</i> /5 KH_2PO_4 + 46.85 c.c. <i>M</i> /10 NaOH, diluted to 100 c.c.	" "	8.00	323
<i>M</i> /20 borax	Walbum, cf. Clark ²	9.24	394
75 c.c. <i>M</i> /20 Na_2CO_3 + 25 c.c. <i>M</i> /20 borax	Kolthoff and Vleeschouwer, cf. Clark ²	9.99	435
50 c.c. <i>M</i> /10 Na_2HPO_4 + 8.26 c.c. <i>M</i> /10 NaOH, diluted to 100 c.c.	" "	11.00	481
<i>M</i> /20 Na_2CO_3	Menzel ¹⁷	11.37	492
	Frery and Nietz ⁶	11.32	
	Kolthoff, cf. Kolthoff and Furman ¹⁴	11.36	
50 c.c. <i>M</i> /10 Na_2HPO_4 + 33.30 c.c. <i>M</i> /10 NaOH, diluted to 100 c.c.	Kolthoff and Vleeschouwer, cf. Clark ²	11.80	507
40 c.c. <i>M</i> /50 $\text{Ca}(\text{OH})_2$ + 10 c.c. <i>M</i> /10 HCl	Cuccodoro ⁴	12.00	547
<i>M</i> /50 $\text{Ca}(\text{OH})_2$	"	12.52	578

It was found necessary to calibrate an electrode every day, as the *E.M.F.* observed with a given buffer solution varied slightly from day to day. For measurements up to pH 10, two points only are necessary to determine the calibration curve, and for this purpose the most conveniently prepared solutions are *M*/20 potassium hydrogen phthalate (pH 3.97) and *M*/20 borax (pH 9.24). Since the *E.M.F.* is a linear function of the pH up to pH 12.5 when calcium ions are present, this calibration suffices for measurements on calcium hypochlorite solutions, but for determinations of pH in sodium hypochlorite solutions of pH higher than 10, it is necessary to have at least two more points on the calibration curve above this pH.

Dole⁵ has shown that the deviation of the sodium curve from the straight line increases with the concentration of sodium ion present in the solution, and since the sodium ion concentration in the standard buffer solutions used for the region above pH 9.24 is between 0.1 and 0.13 *M*, the calibration curve obtained is strictly applicable only to test solutions of similar sodium ion concentration. The necessary conditions are fulfilled by the sodium hypochlorite bleach liquors, but in the liquors buffered with soda ash, the sodium ion concentration always exceeds 0.1 *M* and rises to about 0.25 *M* in the third bleach of a series. This has the effect of making the pH found for such solutions slightly too low. The error increases with rising pH, but at pH 10.5 it probably does not exceed 0.1 pH unit.

III—THE VALIDITY OF GLASS ELECTRODE MEASUREMENTS IN HYPOCHLORITE SOLUTIONS FOR THE DETERMINATION OF HYDROGEN ION CONCENTRATION

Although there is no *a priori* reason to suppose that the presence of oxidising agents like the hypochlorite ion and hypochlorous acid interferes with the determination of hydrogen ion concentration by means of the glass electrode, it is desirable to obtain experimental evidence on this point. The impossibility of measuring the *pH* of hypochlorite solutions by any of the usual methods makes it difficult to obtain a direct check on the working of the glass electrode in such solutions, and it is necessary to proceed in a more indirect way. If a small quantity of sodium hypochlorite is added to a buffer solution of considerable buffer capacity, the *pH* is only slightly altered, and the new *pH* can be calculated by consideration of the sharing of the total base between the two acids, the buffer acid and hypochlorous acid. In the general case, if a_1 and a_2 are the concentrations of two weak monobasic acids with apparent* dissociation constants K'_1 and K'_2 and b is the concentration of total base present, it can be shown⁹ that

$$\frac{K'_1 a_1}{K'_1 + [H^*]} + \frac{K'_2 a_2}{K'_2 + [H^*]} - [H^*] + [OH^*] - b = 0$$

If the *pH* of the mixture is between 4 and 10, the third and fourth terms may be neglected, so that the equation becomes a quadratic in $[H^*]$. In the present instance, the apparent dissociation constant of the buffer acid is readily obtained from its neutralisation curve, and its concentration is known from the composition of the buffer solution. It is necessary to assume a value for the dissociation constant of hypochlorous acid, and its concentration in the mixture can be calculated from the concentration of the added hypochlorite solution and the dilution that takes place when it is added to the buffer solution. The total base present consists of the alkali originally combined with the buffer acid, the alkali combined with hypochlorous acid, and the "free" alkali (*i.e.* the titratable alkali in excess of the hypochlorite equivalent) contained in the hypochlorite solution. By comparing the observed and calculated *pH* values for a mixture of a buffer solution and sodium hypochlorite solution a check on the working of the glass electrode in the presence of hypochlorites is obtained.

Table II gives the results obtained on adding 2 c.c. of 1 *M* sodium hypochlorite solution, 0.1305 *N* in free sodium hydroxide, to 100 c.c. of acetate, phosphate and borate buffers respectively. Three values for the dissociation constant (K') of hypochlorous acid have been recorded in the literature, *viz.* 3.7×10^{-8} at 17° C. (Sand¹⁹), 6.7×10^{-10} at 25° C. (Noyes and Wilson¹⁸), and 1.0×10^{-8} at 25° C. (Soper²⁰), and three calculated values for the *pH* of each mixture are given, corresponding to these three values of K' .

The table shows that when the acetate buffer is employed, the calculated *pH* is the same no matter which of the three recorded values of the dissociation constant is assumed, and that this calculated *pH* is in excellent agreement with the observed value. The assumption of any value for the dissociation constant less than 4×10^{-8} leads to the conclusion that at the *pH* of the acetate buffer, the added hypochlorite is present entirely as hypochlorous acid, and the effect produced is therefore that due to the addition of an

* The dissociation constants referred to in this paper are "apparent" in the sense that concentration and not activity is taken to represent active mass, so that the "constant" varies slightly with the ionic strength of the solution. Following current usage, this apparent dissociation constant is designated K' to distinguish it from the true dissociation constant in terms of activities, K .

Table II

	E.M.F. (milli- volts)	pH			
		Ob- served	Calculated		
			$K' = 3.7 \times 10^{-8}$	$K' = 1.0 \times 10^{-8}$	$K' = 6.7 \times 10^{-10}$
Acetate buffer ...	121	(4.63)	—	—	—
Do. + hypochlorite	132	4.82	4.83	4.83	4.83
Phosphate buffer ...	256	(7.00)	—	—	—
Do. + hypochlorite	285	7.51	7.52	7.78	8.47
Borate buffer ...	384	(9.24)	—	—	—
Do. + hypochlorite	386	9.27	9.27	9.27	9.33

(For the composition of the phosphate and borate buffer solutions see Table I. Acetate buffer—a solution 0.1M in acetic acid and 0.1 M in sodium acetate.)

amount of alkali equal to the total alkali, free and combined, contained in the hypochlorite; consequently, the calculated pH is the same for all three values of the dissociation constant. The agreement between observed and calculated pH thus shows that the glass electrode functions correctly in the presence of hypochlorous acid.

The calculated pH for the borax-hypochlorite mixture is identical with the observed pH if either of the two larger values for the dissociation constant is assumed, and differs from it by only 0.06 pH unit if the extreme value of 6.7×10^{-10} is taken. Here the hypochlorite exists in the mixture almost entirely, or to the extent of about half, as hypochlorite ion, according as the greatest or the least of the values for the dissociation constant is assumed. The agreement between observed and calculated pH values thus provides strong evidence that hypochlorite ion does not interfere with the correct working of the glass electrode.

With the phosphate-hypochlorite mixtures, the three calculated pH values differ widely, and only the value calculated on the assumption that the dissociation constant is 3.7×10^{-8} is in agreement with the observed pH . The results therefore do not provide any independent evidence regarding the validity of the use of the glass electrode in hypochlorite solutions, but they are explicable if the correct value of the dissociation constant of hypochlorous acid is about 3.7×10^{-8} . As will be shown in the next section, electrometric titration of sodium hypochlorite by means of the glass electrode yields this value, indicating that the measurements in solutions where hypochlorous acid and hypochlorite ion play only a minor part in determining the pH are consistent with measurements in solutions in which these substances constitute the sole buffer system.

IV—THE DISSOCIATION CONSTANT OF HYPOCHLOROUS ACID

For the complete understanding of the behaviour of hypochlorite solutions a knowledge of the dissociation constant of hypochlorous acid is essential. As already mentioned, three values for this constant have been recorded, *viz.* 3.7×10^{-8} , 1.0×10^{-8} , and 6.7×10^{-10} . Whilst the first and second values are in moderate agreement, the third is of a different order of magnitude, so that there has been some doubt as to the true value. Electrometric titration provides a useful method of determining the dissociation constant of weak acids, but it only became applicable to hypochlorous acid with the introduction of the glass electrode. The determination is described, and the results are recorded, in the following paragraphs.

The method employed was the titration with 0.2 N hydrochloric acid of solutions of sodium and calcium hypochlorites 0.02 M in hypochlorite ion

(0.04 *N* in available chlorine). Two hundred c.c. of the solution were contained in a 250 c.c. beaker, and the glass electrode and the tip of the side tube of the calomel half-cell were immersed in the solution. The hydrochloric acid was added from a burette, and after each addition of acid the solution was stirred and the *E.M.F.* measured. By means of the Henderson-Hasselbalch equation, $pH = pK' + \log [\text{salt}]/[\text{acid}]$, where $pK' = -\log K'$, the apparent dissociation constant was calculated for various degrees of neutralisation of the hypochlorous acid.

The sodium hypochlorite solution used for the electrometric titrations was prepared from a commercial solution about 5 *N* in available chlorine. Examination showed that part of the free alkalinity of this solution was due to carbonate, which had to be removed before performing the titration. The free alkalinity of the solution was determined by destroying the hypochlorite with neutralised hydrogen peroxide and titrating to the methyl red end-point with standard acid. To 500 c.c. of the concentrated hypochlorite solution were added barium chloride equivalent to the whole of the free alkalinity and concentrated carbonate-free sodium hydroxide solution sufficient to make the solution about 0.2 *N* in free alkali. The precipitated barium carbonate was allowed to settle, and the clear solution drawn off. The excess of barium present was then precipitated by the addition of sodium sulphate solution, the amount required being ascertained by adding the sodium sulphate solution to an aliquot part of the hypochlorite solution contained in a centrifuge tube, until after centrifuging a further addition produced no precipitate. The barium sulphate was separated by centrifuging in stoppered tubes, and the clear solution analysed for free alkali, hypochlorite, chloride, chlorate, and sulphate. From this solution a solution about 0.02 *M* in hypochlorite was prepared for electrometric titration. This solution was 0.00250 *N* in free alkali, 0.0204 *M* in hypochlorite ion, 0.0293 *M* in chloride ion, and 0.0013 *M* in chlorate ion, whilst the amount of sulphate was negligibly small.

Owing to the insolubility of calcium carbonate, calcium hypochlorite solutions containing free alkali are free from carbonate. The calcium hypochlorite solution for electrometric titration was obtained by the dilution of a freshly prepared solution of bleaching powder. The solution used was 0.00195 *N* in free alkali, 0.0200 *M* in hypochlorite ion, 0.0251 *M* in chloride ion, and 0.00054 *M* in chlorate ion.

Fig. 2 shows a typical titration curve for a solution containing sodium hypochlorite. The first "break" in the curve corresponds to the neutralisation of the free alkali, and the second to the completion of the liberation of the hypochlorous acid. The results of four titrations—two of sodium, and two of calcium, hypochlorite—and the derived values of pK' and K' are given in Table III. The table shows that the calculated pK' values are very nearly constant over the range of 10–95% neutralisation, but the value found for 5% neutralisation is slightly lower. The value for half-neutralisation is 7.43, and this is in good agreement with the mean of all the values. Taking this value as the best for the purpose of defining K' by a single figure, the value of K' at room temperature (18–20° C.) is 3.7×10^{-8} , in agreement with Sand's mean value.

Foerster and Jorre⁷ have shown that hypochlorite ion and hypochlorous acid interact to yield chlorate, and this reaction is a possible source of error in the determination of the dissociation constant⁸ of hypochlorous acid by electrometric titration. The results of Foerster⁸ indicate, however, that at

Table III

% Neutralisation of hypochlorous acid	$\frac{[\text{ClO}^-]}{[\text{HClO}]}$	$\log \frac{[\text{ClO}^-]}{[\text{HClO}]}$	pH				Mean pH	Mean pK'	Mean K'
			Sodium hypochlorite		Calcium hypochlorite				
			Expt. 1	Expt. 2	Expt. 3	Expt. 4			
95	19	1.28	8.70	8.71	8.71	8.69	8.70	7.42	3.8×10^{-8}
90	9	0.95	8.38	8.41	8.42	8.39	8.40	7.45	3.6
80	4	0.60	8.00	8.04	8.08	8.05	8.04	7.44	3.6
70	2.33	0.37	7.77	7.83	7.83	7.78	7.80	7.43	3.7
60	1.5	0.18	7.59	7.65	7.65	7.60	7.62	7.44	3.6
50	1	0.00	7.42	7.44	7.46	7.41	7.43	7.43	3.7
40	0.667	-0.18	7.25	7.25	7.28	7.23	7.25	7.43	3.7
30	0.429	-0.37	7.05	7.05	7.08	7.03	7.05	7.42	3.8
20	0.25	-0.60	6.81	6.85	6.80	6.79	6.81	7.41	3.9
10	0.111	-0.95	6.45	6.45	6.40	6.42	6.43	7.38	4.2
5	0.053	-1.28	6.06	6.07	6.02	6.04	6.05	7.33	4.7

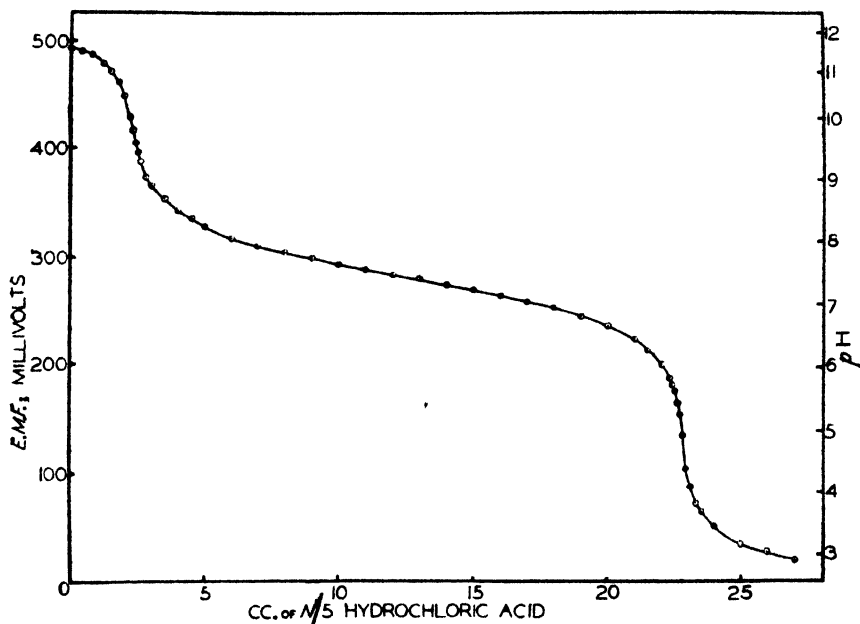


FIG. 2

dilutions as great as that employed in the above titrations, chlorate formation at room temperature is very slow, and this has been confirmed by results obtained in the present work which will be described later. It is therefore probable that the amount of chlorate formation taking place in an hour, the time required for a titration, is negligible, and this conclusion is supported by the close agreement between the concentration of hypochlorite as determined by electrometric titration with acid and by titration with sodium arsenite solution.

From the hydrolysis constant of chlorine in aqueous solution it can be calculated¹ that there is no appreciable formation of chlorine during the titrations until the $p\text{H}$ falls below 4.6, the $p\text{H}$ at which the liberation of hypochlorous acid is complete; hence no error is introduced into the determination by chlorine formation.

V—THE VARIATION OF THE pH OF HYPOCHLORITE SOLUTIONS DURING THE BLEACHING OF COTTON

(1) Introductory

In order to study the changes which take place in the pH of hypochlorite bleach liquors during the bleaching process, a series of experimental bleaches has been carried out, and the pH of the bleach liquor measured by means of the glass electrode at intervals. The cloth used was of American cotton, desized, and scoured by boiling with soda ash solution before bleaching. This preparation is less drastic than is usually employed for white goods, which are generally boiled under high pressure with caustic soda solutions, but it may be regarded as the most severe scouring treatment to which cloth containing coloured stripes can be safely subjected. Compared with a pressure caustic boil, the milder scouring treatment used in these experiments results in a less complete removal of the non-cellulosic substances, whilst in the subsequent bleaching the consumption of hypochlorite and the accumulation of acidic oxidation products in the bleach liquor are correspondingly greater. These factors must affect, in a quantitative sense, the observed changes of pH during bleaching.

It is the practice in many works to use the partially spent bleach liquor from one bleach in making up the liquor for the next, and this procedure has been followed in the present work. In each series consisting of three bleaches, the partially spent liquors from the first and second have been used in preparing the bleach liquors for the second and third bleaches respectively.

(2) Description of Experimental Bleaches

A sample of the grey cloth weighing $6\frac{1}{2}$ lb. was wetted out with hot water, malted overnight in a $\frac{1}{2}\%$ solution of Diastafor, washed, and boiled for 4 hours in 0.2% soda ash solution. After rinsing, the cloth was soured with $N/20$ hydrochloric acid and washed until the pH of the wash-water was about 5. It was then squeezed until it retained about 150% of its weight of water.

The bleaching operation was conducted in an apparatus which enabled the bleach liquor to be circulated continuously from a storage cistern through the cloth piled in a vessel at a higher level, and thence back to the storage cistern. In all the experiments, the ratio of liquor to cloth was $5:1$, so that for $6\frac{1}{2}$ lb. ($=2.84$ kgm), 14.2 litres of liquor were necessary. The amount of water retained in the cloth after the soda ash boil was determined by weighing the wet cloth, and allowance made for it in making up the liquor. At the beginning of each bleach 710 milli-equivalents of available chlorine were added in the form of concentrated calcium or sodium hypochlorite solution, thus making the solution 0.05 N in available chlorine, and after half-an-hour's bleaching a further addition of 355 milli-equivalents was made. Bleaching was continued for $2\frac{1}{2}$ hours, and at intervals the pH of the bleach liquor was measured by means of the glass electrode, and the concentration of available chlorine determined by titration with standard arsenite solution. At the end of the bleach, the circulation was stopped and as much of the liquor as possible squeezed out of the cloth. This partially spent liquor was used in making up the bleach liquor for the next bleach of the series, making due allowance for the residual hypochlorite.

(3) Measurements of pH during Bleaching

The following three series of experimental bleaches were carried out—

(a) with calcium hypochlorite solution, (b) with sodium hypochlorite solution,

and (c) with sodium hypochlorite solution containing 5 g. per litre of soda ash. The calcium hypochlorite solution was prepared from a stock solution 1.98 *N* in available chlorine and 0.0415 *N* in free alkali, and the calculated initial free alkalinity of the bleach liquor was 0.00105 *N*. The available chlorine concentration and free alkalinity of the sodium hypochlorite stock solution were 3.02 *N* and 0.215 *N* respectively, giving a bleach liquor 0.00356 *N* in free alkali.

The consumption of hypochlorite was very rapid in the early stages of the bleach, the available chlorine concentration falling from 0.05 *N* at the beginning to an average value of 0.018 *N* after half an hour. At this point, the concentration was increased by 0.025 *N* by the addition of hypochlorite, and it then fell more slowly, again attaining an average value of 0.018 *N* at the end of the bleach (2½ hours). The partially spent liquor was kept in the storage cistern of the bleaching apparatus until the following day, when about 8 litres of it was utilised in making up the bleach liquor for the next bleach of the series. During this period of storage, it was found that the concentration of available chlorine continued to fall, and was usually only about 0.005 *N* after the liquor had stood for 20 hours. Although the experiments described are not well adapted for exact measurement of the hypochlorite consumption, there is evidence that with the sodium hypochlorite liquors to which additions of soda ash have been made the concentration of available chlorine is lower at the end of the bleach and falls more rapidly when the partially spent liquor is allowed to stand, than with the calcium hypochlorite or sodium hypochlorite liquors containing no added alkali. The variation of the *pH* of the bleach liquors during the various bleaches is recorded in Table IV, and shown graphically in Fig. 3. Owing to the lower free alkalinity of the calcium hypochlorite solution, the initial *pH* (11.05) is lower than that of the sodium hypochlorite solution (11.55). In the first bleach of both the calcium and sodium hypochlorite series, the *pH* falls very rapidly in the early stages of the bleach; there is a rise of *pH* when the addition of hypochlorite is made after half an hour, and then the *pH* falls more slowly until the end of the bleach. When the partially spent liquor is allowed to stand overnight, the *pH* falls considerably, and on making up the liquor for the second bleach, the *pH* attained is much lower than at the beginning of the first bleach. In the second bleach, the course of the *pH* variation is similar to that of the first bleach, except that there is no rapid fall at the beginning, and that the *pH* values are lower than in the first bleach. The third bleach yields results very similar to the second. The principal difference between the calcium and sodium hypochlorite bleaches is that with the former the *pH* is consistently lower than with the latter, the difference amounting to 1 unit after three bleaches.

When sodium hypochlorite solution containing soda ash is used, the fall in *pH* is very much less rapid than with either sodium hypochlorite alone, or calcium hypochlorite. This is due to the buffering action of the carbonate-bicarbonate system, which also prevents any appreciable rise of *pH* when the addition of hypochlorite is made after half an hour. The fall in *pH* during the second and third bleaches of this series is relatively small, and the *pH* at the end of the third bleach was 9.6 as against 8.25 with sodium hypochlorite alone and 7.25 with calcium hypochlorite. The initial *pH* of the first bleach in the soda ash series was 11.2, which is lower than that of 0.05 *M* sodium carbonate solution used as a standard (11.35). The *pH* of a 0.05 *M* solution of the soda ash was measured and found to be 11.15, a result which is probably due to the presence of bicarbonate in the commercial carbonate.

Table IV
pH of Bleach Liquors

Time	Calcium hypochlorite Bleach			Sodium hypochlorite Bleach			Sodium hypochlorite + Soda ash Bleach		
	EB97	EB98	EB99	EB100	EB101	EB102	EB103	EB104	EB105
0 mins.*	11.05	8.55	8.55	11.55	9.35	9.25	11.2	10.1	9.9
5	9.25	8.45	8.35	10.5	9.25	9.2	—	—	—
15	8.95	8.3	8.15	9.7	9.05	9.1	10.95	10.0	9.85
30**	8.7	8.15	8.0	9.35	8.9	8.95	10.8	9.95	9.8
35	8.85	8.4	8.35	9.8	9.2	9.2	10.75	—	—
45	8.7	8.2	8.1	9.4	9.1	9.15	10.65	9.9	9.8
60	8.5	8.0	7.9	9.2	8.9	9.0	10.5	9.85	9.75
90	8.25	7.65	7.6	8.8	8.6	8.65	10.3	9.8	9.7
120	8.1	7.45	7.4	8.5	8.45	8.4	10.2	9.75	9.65
150	7.95	7.35	7.25	8.35	8.3	8.25	10.15	9.7	9.6
23 hours	6.6	6.0	—	6.75	7.0	7.15	9.8	9.6	—

* Before circulation of the bleach liquor through the cloth.

** Addition of hypochlorite immediately after this measurement.

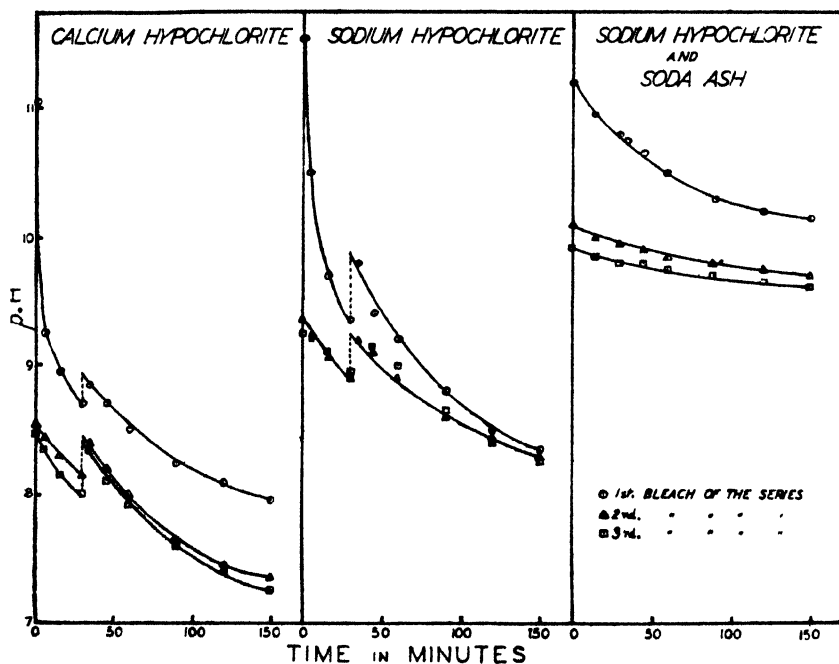


FIG. 3

Three similar series of bleaches were carried out, using a cloth which had been washed but not soured after the soda ash boil. Results qualitatively similar to those recorded in Table IV were obtained, but the pH values observed were slightly higher than those for the soured cloth. This is no doubt due to the alkalinity of the unsoured cloth, since it was found that in a typical instance, whereas the cloth washed with water after the soda ash boil had an ash alkalinity of 6.3 milli-equivalents per 100 g., after souring and washing, the ash alkalinity was only 1.1.

It is sometimes stated that the carbon dioxide of the air plays an important part in bleaching by means of hypochlorites, by neutralising the free alkalinity of the bleach liquor and liberating hypochlorous acid from its salt. Experiments were therefore made in which calcium and sodium hypochlorite solutions of the composition used in the bleaches were circulated in the bleaching apparatus, with only a single layer of a well-bleached cloth present. With sodium hypochlorite, the fall in pH in $2\frac{1}{2}$ hours was from 11.5 to 11.05, and a similar rate of fall was obtained with a calcium hypochlorite solution. The effect of atmospheric carbon dioxide on the pH of bleach liquors under the conditions employed is therefore small, and quite insufficient to explain the rapid fall in pH which takes place during the first 15 minutes of a bleach. Since the effect of atmospheric carbon dioxide on the pH of a sodium hypochlorite solution containing soda ash would be the same as the effect on the soda ash alone, the blank experiment in this instance was made by circulating a $\frac{1}{2}\%$ solution of soda ash through cloth exactly as in a bleach. In $2\frac{1}{2}$ hours the pH fell by 0.3 unit. A $\frac{1}{2}\%$ solution of sodium carbonate is not in equilibrium with the carbon dioxide of the air; according to the results of Walker, Bray, and Johnston,²¹ carbon dioxide is absorbed until about 40% of the total base is present as bicarbonate. The pH of such a carbonate system is about 10, so that in the above experiment, equilibrium with atmospheric carbon dioxide was by no means reached after circulation for $2\frac{1}{2}$ hours.

(4) Examination of Spent Liquors

At the end of each bleach, a sample of the liquor was taken and kept in a well-stoppered bottle. The concentration of residual available chlorine fell

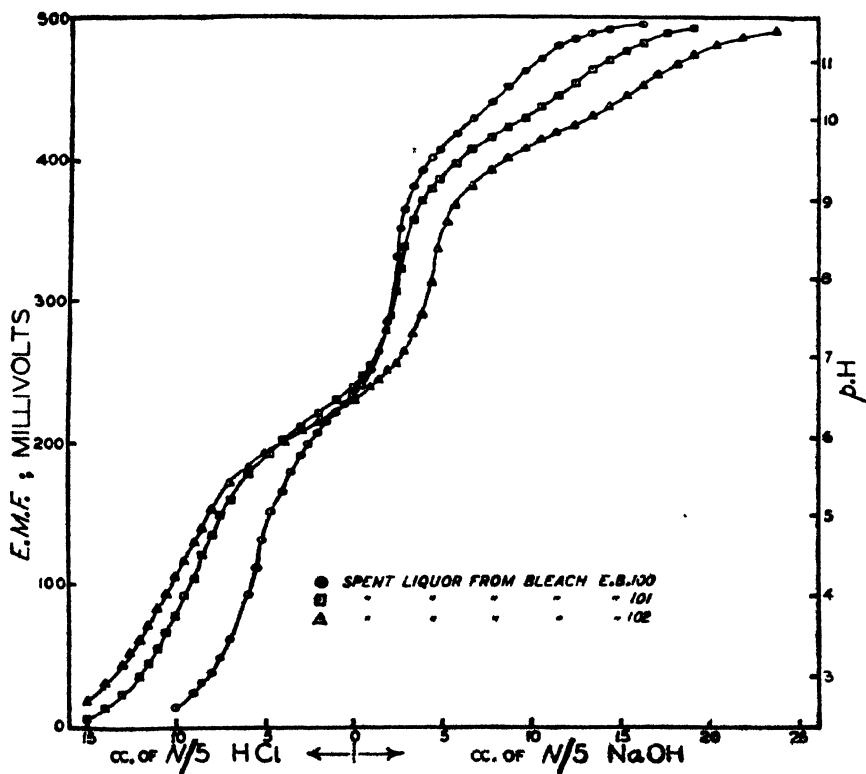


FIG 4

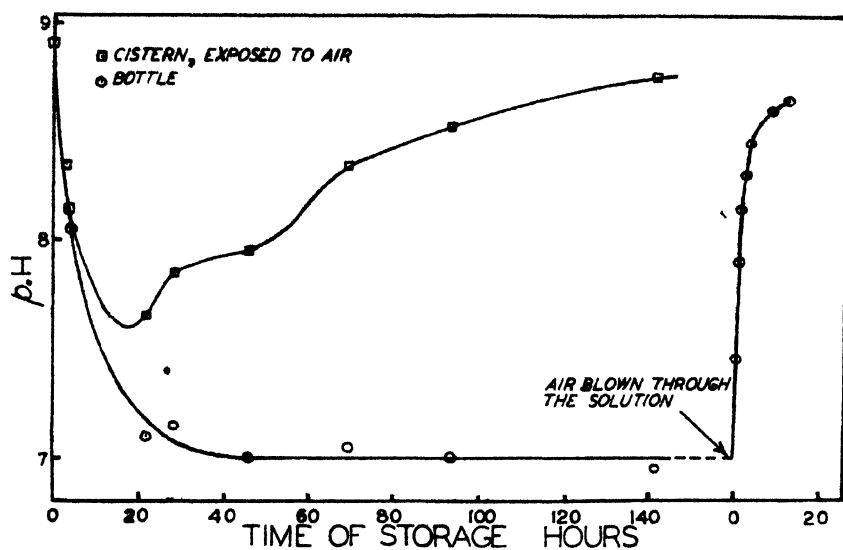


FIG. 5

rather rapidly, and when there was no more hypochlorite present, as shown by the failure to colour starch-iodide paper, the spent liquors from the sodium and calcium hypochlorite bleaches were titrated electrometrically with acid and alkali by means of the glass electrode. Fig. 4 shows the results of the titration of 200 c.c. of each of the three sodium hypochlorite spent liquors with $N/5$ hydrochloric acid and $N/5$ sodium hydroxide solutions. The results for the three solutions are qualitatively similar, and show that the amount of buffering substances in solution increases progressively from the first to the third bleach of the series, as might be expected from the use of the partially spent liquors from the first and second, in preparing the bleach liquors for the second and third bleaches respectively. The titration curves agree closely with the titration curve of sodium carbonate with hydrochloric acid, except that there is no well-defined "break" corresponding to the complete liberation of carbonic acid. The gradual fall of the curves from pH 5 suggests the presence of some weak acid or acids stronger than carbonic acid. Chemical tests confirmed the presence of carbonic acid. Hence the spent liquors, which have a pH of from 6.45 to 6.6, probably contain a certain amount of a rather strong organic acid present almost entirely as the sodium salt, and a larger amount of carbonic acid present mainly as bicarbonate, but partly as the free acid.

When a spent liquor from a sodium hypochlorite bleach, which has been kept in a closed bottle until there is no hypochlorite left, is then exposed to the air, the pH gradually rises. This is illustrated by Fig. 5, which shows the change of pH with time in two samples of a spent liquor, one of which was left in the cistern of the bleaching apparatus, exposed to the air, while the other was kept in a closed bottle. The pH of both samples fell at first, corresponding to the gradual consumption of the residual hypochlorite, but while the pH of the sample in the bottle fell to a practically constant value of 7.0; the pH of the spent liquor in the jar began to rise again and reached a value of 8.75 after six days. A similar rise in pH was produced in a few hours by passing a current of air through the spent liquor which had been kept in a stoppered bottle (Fig. 5). This behaviour is readily accounted for by the

presence of carbonic acid and sodium bicarbonate. In any carbonate solution there is an equilibrium between the carbonate ion CO_3^{--} , the bicarbonate ion HCO_3^- , and free carbonic acid H_2CO_3 , and the latter is also in equilibrium with the carbon dioxide in the gas phase above the solution. Thus for a given amount of base in the solution, the state of the carbonate equilibrium, and hence the pH , are defined by the partial pressure of carbon dioxide in equilibrium with the solution. The partial pressure of carbon dioxide in ordinary air is about 0.0003 atmosphere, and if a solution containing a carbonate system in equilibrium with a higher pressure of carbon dioxide than this is exposed to the air, carbon dioxide will be given off and the pH of the solution will rise, until equilibrium with the atmospheric carbon dioxide is attained. In the present instance, the pH of the unexposed spent liquor and the indication of the approximate amount of base combined as bicarbonate given by electrometric titration showed that the equilibria in the solution corresponded to a partial pressure of carbon dioxide considerably in excess of that in the atmosphere. Consequently, on exposing the solution to the air, carbon dioxide was given off and the pH rose. This loss of carbon dioxide was also shown by electrometric titration of the spent liquor before and after exposure to the air, which indicated that the total concentration of weak acids was less after exposure than before.

The spent liquors from the three calcium hypochlorite bleaches EB 97, 98, and 99 were titrated electrometrically in the same way as those from the sodium hypochlorite bleaches after being kept in closed bottles until there was no more hypochlorite left. The results obtained with the three spent liquors were very similar and the titration curve for one of them (EB99) is given in Fig. 6. As with the sodium hypochlorite spent liquors, clear evidence of the presence of carbonic acid is given by the course of the titration curves, and with the calcium liquors there is additional evidence given by the precipitation of calcium carbonate when the pH reached about 8.5. The titration curve also yields evidence of the presence of a weak acid stronger than carbonic acid, combined as calcium salt, whilst the low pH of the spent liquors (5.15–5.35) indicates that most of the carbonic acid present is in the free state.

Some of the spent liquor from the calcium hypochlorite bleach EB99 was exposed to the air for ten days and then again titrated. The titration curve obtained is included in Fig. 6 and shows the loss of carbon dioxide in a very striking way. The rapid rise of the pH on the addition of alkali shows that the carbonic acid originally present had almost entirely disappeared. The dotted curve in Fig. 6 is the neutralisation curve of a strong acid and a strong base, and by comparison of this curve with the titration curve of the spent liquor exposed to the air, the presence of some weak acid considerably stronger than carbonic acid is confirmed. At the pH of the spent liquor, this acid is seen to be practically entirely in the combined state.

The spent liquors from the calcium hypochlorite bleaches were practically colourless, while those from the sodium hypochlorite bleaches were slightly yellowish. On titration with alkali, both the calcium and sodium solutions became pale yellow; the sodium solutions gave a small amount of a brownish precipitate containing organic matter and magnesium, the latter presumably being derived from the cloth, whilst with the calcium solutions a more copious precipitate consisting mainly of calcium carbonate was obtained. The spent liquors from the bleaches with sodium hypochlorite solution containing soda ash were pale yellow at the end of the bleaches, but acquired a much deeper

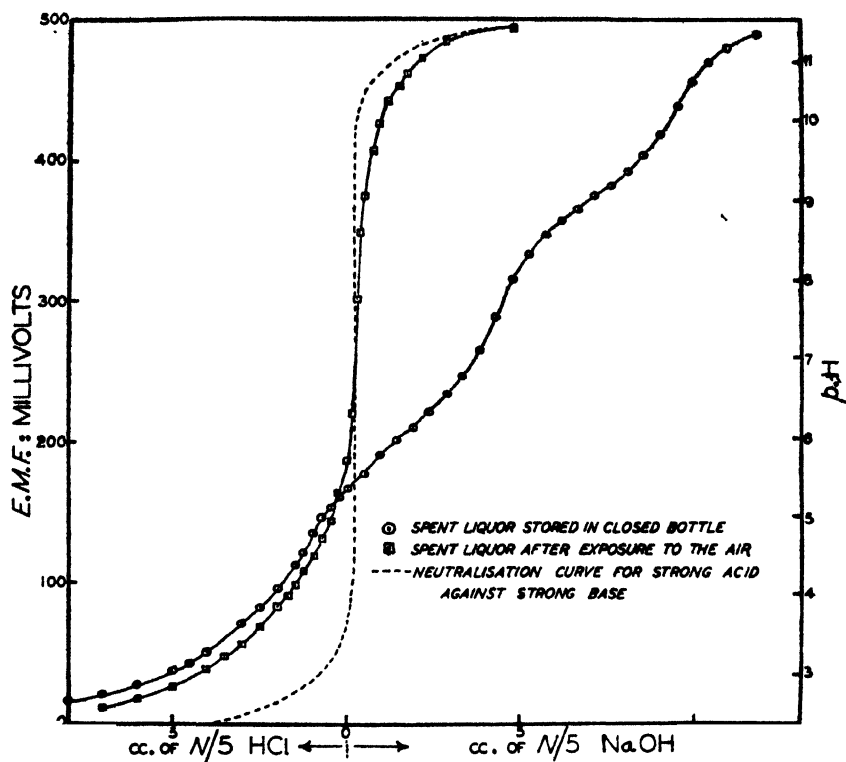


FIG 6

yellow colour on standing; on acidification they were rendered almost colourless and opalescent.

When the samples of the spent liquors from the calcium hypochlorite bleaches were taken at the end of the bleach they were quite clear, but after they had stood overnight a small quantity of a white precipitate was found to have settled out. This was separated, and found to be insoluble in dilute acetic acid, but soluble in dilute hydrochloric acid. On making the hydrochloric acid solution alkaline with ammonia, a granular precipitate was formed, thus suggesting that the substance was calcium oxalate. This supposition was supported by the observation that when either the original precipitate or that obtained by dissolving it in hydrochloric acid and making alkaline with ammonia was warmed with dilute sulphuric acid, the resulting solution reduced a considerable quantity of permanganate. Oxalic acid can be only an intermediate product in the bleaching process, since it is itself easily oxidised to carbon dioxide by hypochlorous acid.¹⁰

It is perhaps worthy of note that although the spent liquors soon became incapable of giving a blue coloration with starch-iodide paper, yet when this stage had been reached the solutions were able to liberate a little iodine from potassium iodide on acidification with acetic acid. Control experiments showed that this behaviour was not due to the small amount of chlorate present in the spent liquors, and it is possibly to be attributed to the presence of some chlorinated substance or substances. If the hypochlorite is consumed partly by chlorination processes, free alkali should be liberated, and this should tend to raise the pH of the solution. If free alkali is actually

liberated in this way, its effect on the pH is entirely masked by the production of acidic products by oxidation processes.

(5) The Consumption of Hypochlorite by Spent Liquors and the Stability of Hypochlorite Solutions at Various pH Values

As already mentioned, after the end of a bleach the concentration of available chlorine in the bleach liquor continued to fall until ultimately there was none left. For example, in a sodium hypochlorite bleach the concentration of available chlorine at the end of the bleach was 0.0180 N , and it fell to 0.0041 N in 24 hours and to zero in 144 hours. It is known from the work of Foerster^{6, 7} that hypochlorite solutions decompose spontaneously with the formation of chlorate, but his results indicate that the consumption of hypochlorite in this reaction is much less rapid than that found in the partially spent bleach liquors. Experiments were therefore made in which the rate of consumption of hypochlorite by spent liquors was compared with the rate of spontaneous decomposition of hypochlorite solutions of corresponding pH .

Five c.c. of a sodium hypochlorite solution 2.235 N in available chlorine were diluted to 500 c.c. with completely spent liquors from the bleaches EB102 (sodium hypochlorite) and EB105 (sodium hypochlorite and soda ash), the pH measured with the glass electrode, and the rate of consumption of the hypochlorite at room temperature followed by titration of 50 c.c. portions with $N/20$ sodium arsenite solution. Hypochlorite solutions of the same concentration and approximately the same pH were prepared by diluting 5 c.c. of the stock hypochlorite solution to 500 c.c. with water containing the appropriate amount of hydrochloric acid, and the concentration change followed in the same way. The results obtained are given in Table V, and

Table V

Hypochlorite + Spent Liquor				Hypochlorite Alone					
pH	8.15	9.4		7.05		8.2		9.6	
pH	7.25	9.2		6.95		8.15		9.4	
Time (hours)	Available Chlorine	Time (hours)	Available Chlorine	Time (hours)	Available Chlorine	Time (hours)	Available Chlorine	Time (hours)	Available Chlorine
0	0.02235 N	0	0.02235 N	0	0.02235 N	0	0.02235 N	0	0.02235
0.5	0.0173	0.5	0.01475	1.1	0.0221	1.0	0.02225	1.0	0.0223
1.6	0.01495	1.5	0.0123	3.45	0.0220	3.35	0.0222	3.25	0.02225
2.6	0.01355	3.1	0.0099	6.05	0.02185	5.8	0.0221	5.8	0.0222
4.5	0.01155	4.75	0.0082	22.6	0.0210	22.3	0.0219	22.3	0.02205
6.75	0.00975	6.25	0.00685						
23.35	0.0045	22.75	0.00145						

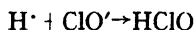
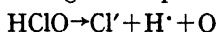
show that the consumption of hypochlorite in the spent liquors is very much more rapid than in the hypochlorite solutions of corresponding pH containing no spent liquor. That the rapid consumption of hypochlorite by the spent liquors was not due to catalysed auto-decomposition of the hypochlorite was shown by again adding hypochlorite to the spent liquor after the first addition had been consumed, when it was found that the fall of the concentration of available chlorine was very much slower than after the first addition. The results suggest that the spent liquors contain organic matter from the cloth, rendered soluble by the bleaching process, and which is capable of further oxidation by hypochlorite. The yellow colour of the

spent liquors was almost completely destroyed by the addition of hypochlorite, a behaviour which is explicable on the oxidation hypothesis.

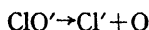
(6) The Effect of the Consumption of Hypochlorite on the pH of Hypochlorite Solutions

Apart from the effect on the pH of bleach liquors of the acidic products formed during bleaching, the pH may fall merely on account of the consumption of the hypochlorite. This latter effect is shown by consideration of the simple case where a hypochlorite solution is reduced by means of a reaction which yields no acidic products, *e.g.* by treatment with a solution of pure hydrogen peroxide. A 0.02 *M* sodium hypochlorite solution containing exactly equivalent amounts of hypochlorous acid and sodium hydroxide has a pH of about 9.7 (cf. Fig. 2). If such a solution is decomposed by means of hydrogen peroxide, the only products are sodium chloride, oxygen and water, so that the resulting solution is neutral, *i.e.* its pH is 7. If now the pH of the hypochlorite is above the equivalence point (pH 9.7), *i.e.* if the solution contains free alkali, the destruction of the hypochlorite will leave a solution containing the original amount of free alkali in addition to the neutral products; the pH of the solution is therefore that corresponding to this concentration of alkali, and calculation shows that it is almost identical with the original pH. On the other hand, if the pH of the hypochlorite solution is below the equivalence point, the solution contains hypochlorous acid, and this on reduction yields an equivalent amount of hydrochloric acid, which causes the resulting solution to have an acid reaction. For example, if the pH of a 0.02 *M* sodium hypochlorite solution is 7.43, the point of half-neutralisation of hypochlorous acid, the solution is 0.01 *M* in hypochlorous acid; on reduction, the solution is 0.01 *M* in hydrochloric acid, so that in the absence of all buffering substances, its pH is 2.

The course of the pH variation of a solution containing hypochlorous acid and hypochlorite ion due to the gradual consumption of the hypochlorite in oxidising processes such as bleaching may be calculated from theoretical considerations. Little is known as to the mechanism of bleaching by hypochlorites, but it can be shown that whether hypochlorite ion or hypochlorous acid is the active bleaching agent, the effect of the consumption of the hypochlorite on the pH is the same. If hypochlorous acid takes any part in the oxidation, hydrochloric acid is produced, and this acts on the hypochlorite ion to liberate an equivalent amount of hypochlorous acid. The reactions may be expressed by the following ionic equations—



so that the net effect is



i.e. the same as if hypochlorite ion were the sole oxidising agent. While the hypochlorite ion is being consumed, the pH of the solution is determined by the Henderson-Hasselbalch equation, and when the hypochlorite ion is very nearly used up, the pH falls steeply to that of a solution of hypochlorous acid. Thus in a solution with an initial total concentration of hypochlorous acid, free and combined, equal to *a*, of which a fraction *x* is combined, the initial pH is defined by the equation $\text{pH} = \text{p}K' + \log x/(1-x)$; if now a fraction *y* of the total available chlorine is consumed in an oxidation process yielding neutral products, the concentration of hypochlorous acid remains almost constant until *y* is nearly equal to *x*, and up to this point the pH is given by

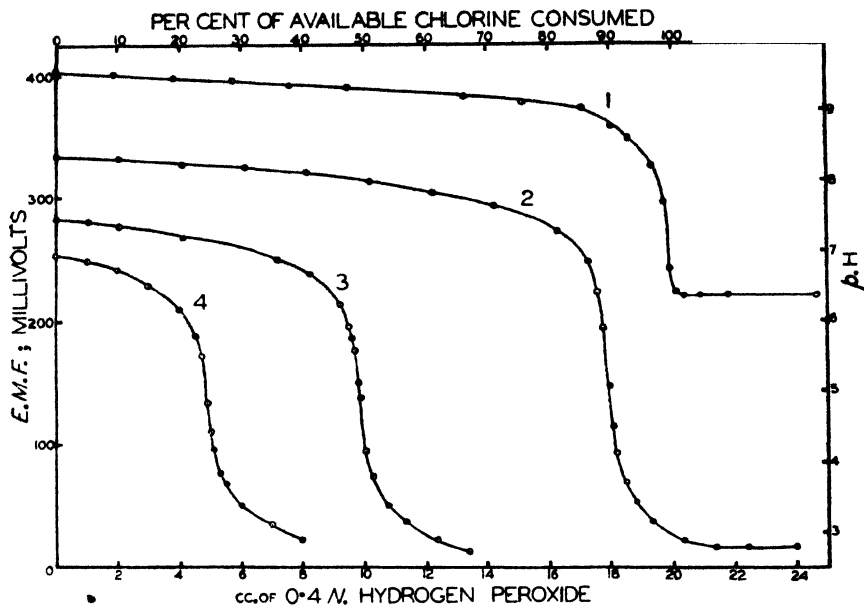


FIG 7

Curve 1—HClO 100% neutralised Curve 3—HClO 50% neutralised.
 „ 2—HClO 90% „ „ 4—HClO 25% „

the equation $pH = pK' + \log(x/y)/(1-x)$. The Henderson-Hasselbalch equation does not hold at the beginning and the end of the neutralisation of a weak acid, so that the above equation breaks down when y approaches x . Beyond the stage when the hypochlorite ion is nearly all consumed, the hydrochloric acid produced by the reduction of hypochlorous acid interacts with the remaining hypochlorous acid to yield chlorine, and the equilibrium in the solution is that corresponding to the equation—



The equilibrium constant of this reaction, the hydrolysis constant of chlorine in aqueous solution, is known, and the hydrogen ion concentration corresponding to the consumption of any fraction of the hypochlorous acid can be obtained by the solution of a cubic equation. During the consumption of the hypochlorous acid, the pH gradually falls, and when the consumption is complete, the pH attains the value corresponding to a solution of hydrochloric acid of concentration $a(1-x)$, the concentration of hypochlorous acid in the original solution. In the special case where the original hypochlorite solution is stoichiometrically neutral, the Henderson-Hasselbalch equation cannot be applied, and during the reduction of such a solution, until almost the whole of the available chlorine has been consumed, the hydrogen ion concentration is defined by the equation $[H^+] = \sqrt{K'K_w}/\bar{a}(1-y)$, where K_w is the ionic product of water.

Experimental confirmation of these theoretical deductions was obtained by the electrometric titration of solutions of wholly and partially neutralised hypochlorous acid with a neutral solution of hydrogen peroxide. Electrometric titration of the hydrogen peroxide solution with acid and alkali showed that it contained no buffering substances which would interfere below pH 10.

Two hundred c.c. of a calcium hypochlorite solution 0.02 *M* in hypochlorite ion were brought to the desired initial *pH* by the addition of the appropriate volume of *N*/5 hydrochloric acid, and the solution titrated electrometrically with a standard solution of hydrogen peroxide approximately 0.4 *N*. The results obtained with solutions in which the hypochlorous acid was 25, 50, 90, and 100% neutralised respectively, are shown in Fig. 7. The figure shows that the experimental results are in agreement with the theoretical deductions. Thus with the solution in which the hypochlorous acid was initially 50% neutralised (*pH* 7.43), the *pH* falls steeply to the *pH* of a solution of hypochlorous acid when 50% of the available chlorine has been consumed, and calculation shows that up to this point the experimental and theoretical curves are in good agreement. As already mentioned, when a stoichiometrically neutral hypochlorite solution is reduced by hydrogen peroxide, the resulting solution should have a *pH* of 7. It could hardly be expected that exactly this *pH* would be obtained experimentally, since a very small error in the neutralisation of the hypochlorous acid would cause a relatively large error in the final *pH* owing to the fact that the final solution is unbuffered. Curve 1 of Fig. 7 gives the results obtained with a solution which was intended to be stoichiometrically neutral, but the final *pH* of 6.35 shows that actually there must have been a slight deficiency of alkali. The curve shows the feature characteristic of a stoichiometrically neutral solution in that the *pH* falls steeply when the hypochlorite is all reduced, and then remains constant on further addition of hydrogen peroxide. The results show that the higher the *pH* of a hypochlorite solution, the more strongly is it "buffered" with respect to the effect of hypochlorite consumption.

(7) General Discussion

In the early stages of bleaching by means of sodium or calcium hypochlorite, the acidic products of the bleaching process reduce the *pH* by neutralising the free alkali, and the consumption of the hypochlorite has no effect. As soon as the equivalence point is reached, however, the action of the acids produced is supplemented by an effect due to the reduction of hypochlorite. It has been seen in Section V (6) that at high *pH* values this latter effect is of little importance. At *pH* values below 9.7, the buffer system consists of partially neutralised hypochlorous and carbonic acids—the stronger acid produced by the bleaching being completely neutralised at *pH* values obtaining during actual bleaching. This buffer system is acted on by the acids continually being produced by the bleaching process, and it is also modified by the gradual consumption of the hypochlorite in the manner already described, so that the *pH* gradually falls. The rapid fall in the early stages of the bleach is due to the rapidity of bleaching and consequent rapid formation of acidic products on the one hand, and the relatively small buffer capacity of hypochlorite solutions at *pH* values between 11 and 8.5 on the other. In the later stages, the rate of fall of the *pH* is much less, due partly to the slowing down of the bleaching and partly to the relatively high buffer capacity of hypochlorite solutions between *pH* values of 8.5 and 6.5. After the end of the bleach, when the partially spent liquor is allowed to stand, the effect of the gradual consumption of the hypochlorite on the *pH* assumes greater importance, but the *pH* is prevented from falling to the low value which would be attained in the absence of buffering substances by the buffer action of the carbonate system and of the salt of the unknown weak acid which has been shown to be present. The completely spent liquors contain

this acid present almost entirely as salt, and carbonic acid present partly as bicarbonate and partly as free acid.

The free alkalinity of calcium hypochlorite solutions is limited by the small solubility of calcium hydroxide, which is only about 0.04 *N*, so that if a bleach liquor is prepared by dilution of a concentrated stock solution, its free alkalinity must be small. This probably accounts, at least to some extent, for the lower *pH* values obtained in calcium than in sodium hypochlorite bleaches. In order to keep the *pH* as high as possible during bleaching, it would thus be advantageous to prepare the bleach liquor directly from bleaching powder, instead of by dilution of a concentrated stock solution.

Owing to the slight solubility of calcium carbonate it might be expected that a precipitate would be formed during bleaching with calcium hypochlorite. In the first bleach of the calcium hypochlorite series no precipitation was observed, but in the second and third bleaches it was noticed that after the addition of fresh hypochlorite half an hour from the start, a sample of the bleach liquor became turbid through precipitation of carbonate. The succeeding sample was clear, indicating that the precipitate had either been dissolved or filtered out by the cloth. Similar observations were made on making up the bleach liquor for the third bleach from the partially spent liquor from the second bleach. This precipitation is evidently due to the action of the free lime in the fresh hypochlorite solution on dissolved calcium bicarbonate or carbonic acid. That some filtering out of precipitated carbonate by the cloth does take place is shown by determinations of the ash alkalinity of the cloth before and after bleaching. In the bleach EB99, the ash alkalinity of the cloth before bleaching was 1.1 milli-equivalents per 100 g., whereas after bleaching and thorough washing it was 4.2. As acidic products continue to be formed during bleaching, the calcium carbonate formed during the early stages must gradually dissolve, thus exerting a buffer action, but it is probable that the maximum possible buffer action is not shown on account of the slowness of the attainment of equilibrium between the calcium carbonate and the solution. Such a behaviour would help to account for the more rapid fall of *pH* in calcium than in sodium hypochlorite bleach liquors.

The *pH* variation in the bleach liquors containing sodium hypochlorite and soda ash is confined to the region above the hypochlorite equivalence point, so that it must be due almost entirely to the action of the acidic products of the bleach and atmospheric carbon dioxide on the carbonate buffer system. As already mentioned, the *pH* at which a carbonate solution 0.1 *N* in total base is in equilibrium with atmospheric carbon dioxide is about 10, so that at *pH* values above 10 all the carbon dioxide produced will remain in the solution. At lower *pH* values it must escape into the atmosphere as fast as it can diffuse out of the bleaching apparatus, and a similar behaviour must be shown by calcium and sodium hypochlorite liquors when the *pH* values at which they are in equilibrium with atmospheric carbon dioxide are reached. This is well illustrated by the curve in Fig. 5 showing the changes in *pH* occurring in a partially spent sodium hypochlorite liquor left in the cistern of the bleaching apparatus. The *pH* fell to a minimum and then rose again, suggesting that the partial pressure of carbon dioxide in the cistern was initially higher than that in the atmosphere, owing to the production of carbon dioxide being more rapid than its diffusion out of the cistern; when the production of carbon dioxide ceased, the partial pressure in the cistern was reduced by diffusion into the surrounding air, and the *pH* therefore rose.

The results obtained in the three series of bleaches show that when calcium or sodium hypochlorite is used, the pH falls into the region where the attack on cellulose is relatively rapid, but that this can be effectively prevented by using a sodium hypochlorite solution containing 0.5% of sodium carbonate.

The experimental bleaches were conducted by Mr. G. Hughes.

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Addendum

Since this paper was written, a series of papers from the Forest Products Laboratories of Canada, dealing with the bleaching of wood pulp has come to the notice of the author. Yorston (*Pulp and Paper Mag. Canada*, 1931, 31, 374) has described the use of the glass electrode of the type introduced by MacInnes and Dole, in conjunction with a valve potentiometer due to Elder, for the measurement of the pH of hypochlorite bleach liquors. By the electrometric titration of a solution of hypochlorous acid, he found the dissociation constant of the latter to be 4×10^{-8} , in excellent agreement with the value recorded in the present paper. Rashback and Yorston (*Forest Products Laboratories of Canada Quarterly Review*, 1931, No. 7, p. 12) have shown that the neutralisation of the free lime in calcium hypochlorite bleach liquors is mainly due to the formation of carbon dioxide, and Yorston (*Pulp and Paper Mag. Canada*, 1932, 33, 74) has shown that such liquors may be buffered at about pH 9 by the addition of magnesia.

In a paper published after this paper was written, Voigtman and Rowland (*Paper Trade J.*, 1932, 95; *T.A.P.P.I. Section*, p. 96) have described "The Assembly and Calibration of the Glass Electrode for use in the Determination of pH of Solutions during Bleaching," and give an example of the pH changes during the bleaching of a sulphite pulp, as measured with the electrode. Their method of measuring the glass electrode *E.M.F.* is identical with that commonly employed for the measurement of hydrogen electrode *E.M.F.*'s, except that an extremely sensitive galvanometer is used.

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Received 27/3 33

EDITORIAL NOTE

Since receipt of the above Memoir attention has been drawn to a recent paper by Britton & Dodds (*Trans. Faraday Soc.*, 1933, 29, 537) in which a value for the dissociation constant of hypochlorous acid of 3.2×10^{-8} at 15° C. was found.

22—THE ACCURATE MEASUREMENT OF SPINDLE SPEED

By G. R. STANBURY

(Wool Industries Research Association)

The worsted spinning department of the Wool Industries Research Association has been engaged recently in spinning yarn with a large range of twists on the same count, for use in some hosiery experiments.

One of the problems associated with this work has been the accurate measurement of the twist inserted in the yarn as distinct from the ordinary "calculated" twist, which depends on the three assumptions—

- (a) That the diameters of the whorle and driving cylinder are accurately known.
- (b) That the thickness of the driving tape is negligible.
- (c) That there is no slip between the driving tape and the whorle.

In 1927, in this *Journal*, an account was given of the methods available for the accurate measurement of spindle speeds by Priestman and Stevenson,¹ and readers are referred to this and a subsequent paper by Stevenson and Marsh,² for an account of the general principles involved in the use of the stroboscope, and also for a description of the very useful stroboscope suggested by Bliss and designed by Stevenson, which has been found so useful for research purposes.

The main principles involved in the stroboscopic measurement of spindle speed may be summarised briefly as follows—

If a body is rotating about an axis with a speed S , and is illuminated by flashes of light whose frequency is either S or any exact multiple of S , or alternatively is observed through a slit whose frequency of opening and shutting is S , it appears to be stationary, the rapid succession of identical images which are presented to the eye being blended into one image.

If the body (in our case a spindle) is moving faster than the frequency of the flashes, each image presented to the eye will be a trifle further round than the previous one and will give the appearance of a spindle moving slowly in the direction of motion of the spindle. If, on the other hand, the spindle is running more slowly than the flash frequency, it will have the appearance of moving slowly backwards, the revolutions made by the image in a minute, being the difference between the speed of the flashes and the actual speed of the spindle.

For every type of stroboscope, however, the accurate measurement of the actual frequency of the light flashes, or the speed of rotation of the slit, is a matter of extreme difficulty owing to the effect on the speed of the power absorbed by the counting mechanism. The obvious alternative is to measure the speed in terms of the much more slowly moving main driving shaft, which is quite unaffected by the application of a speed counter and which, moreover, does not enter into the actual calculation of twist at all. This principle has been used by Stevenson in the following way.

Round the tin cylinder is pasted a piece of paper, divided equally into 40 parts, every division of which is indicated by a prominent black dash. With the cylinder running at 600 r.p.m. it is clear that 24,000 dashes will pass any given point per minute. If the flashes illuminate them 6,000 times per minute (assuming a 10 to 1 driving ratio from cylinder to whorle), every fourth mark will arrive at exactly the same place for successive flashes and the cylinder will appear to be standing still.

In addition to the band divided into 40 parts, there is placed adjacent to it another band divided into 39 parts, each part being marked by a conspicuous dot. This number is, of course, $2\frac{1}{2}\%$ less than 40, and in order to make these marks appear stationary, it is necessary for the flash frequency to be $2\frac{1}{2}\%$ slower.

In addition to these two bands, there are five others carrying respectively 38, 37, 36, 35, and 34 equidistant marks.

It is possible, therefore, to adjust the stroboscope speed to be any multiple of $2\frac{1}{2}\%$ (up to 15%) less than the "standard" speed, corresponding to an exact 10 to 1 ratio. Knowing this speed, the actual spindle speed can then be determined by measuring the number of revolutions of the spindle backwards or forwards as described previously.

In practice the procedure outlined above has certain minor disadvantages. In the first place it is only possible to use the mirror stroboscope in a specially darkened room, so that it is not very suitable for mill use. Secondly, it is difficult to make a paper band exactly equal in length to the circumference of the tin cylinder.

Both these difficulties have been overcome by using a flat circular disc mounted on the face of a bush which can be fitted on to the end of the main driving shaft. This disc is made of $\frac{3}{8}$ in. thick aluminium, and is 16 in. diameter. It is painted white and round the disc and near to its edge is a circle consisting of 40 black dots each $\frac{3}{8}$ in. diameter spaced equally apart. About $\frac{3}{4}$ in. nearer the centre is another ring of 39 dots spaced equally apart, and so on for the various other rings. Successive rings of dots are painted in different colours which show up vividly against the white background and are easily distinguishable. This makes it possible to use an ordinary hand portable stroboscope under ordinary lighting conditions.

Another advantage with this disc is that it can be easily and quickly transferred from one frame to another. It is shown fitted on to a frame in Fig. 1.

Under certain circumstances it is useful to have a check on the method described above and the following procedure can then be adopted.

The stroboscope speed is synchronised with the mean balloon speed and then directed on to the disc. If the "slip" is an exact multiple of $2\frac{1}{2}\%$, one of the rings will appear stationary, but this is not very often the case. What will be seen on most occasions is a slow rotation of one of the circles of dots in one direction, and a rotation of an adjacent circle in the reverse direction. It can be shown that if—

B=spindle speed in r.p.m.

S=cylinder speed in r.p.m.

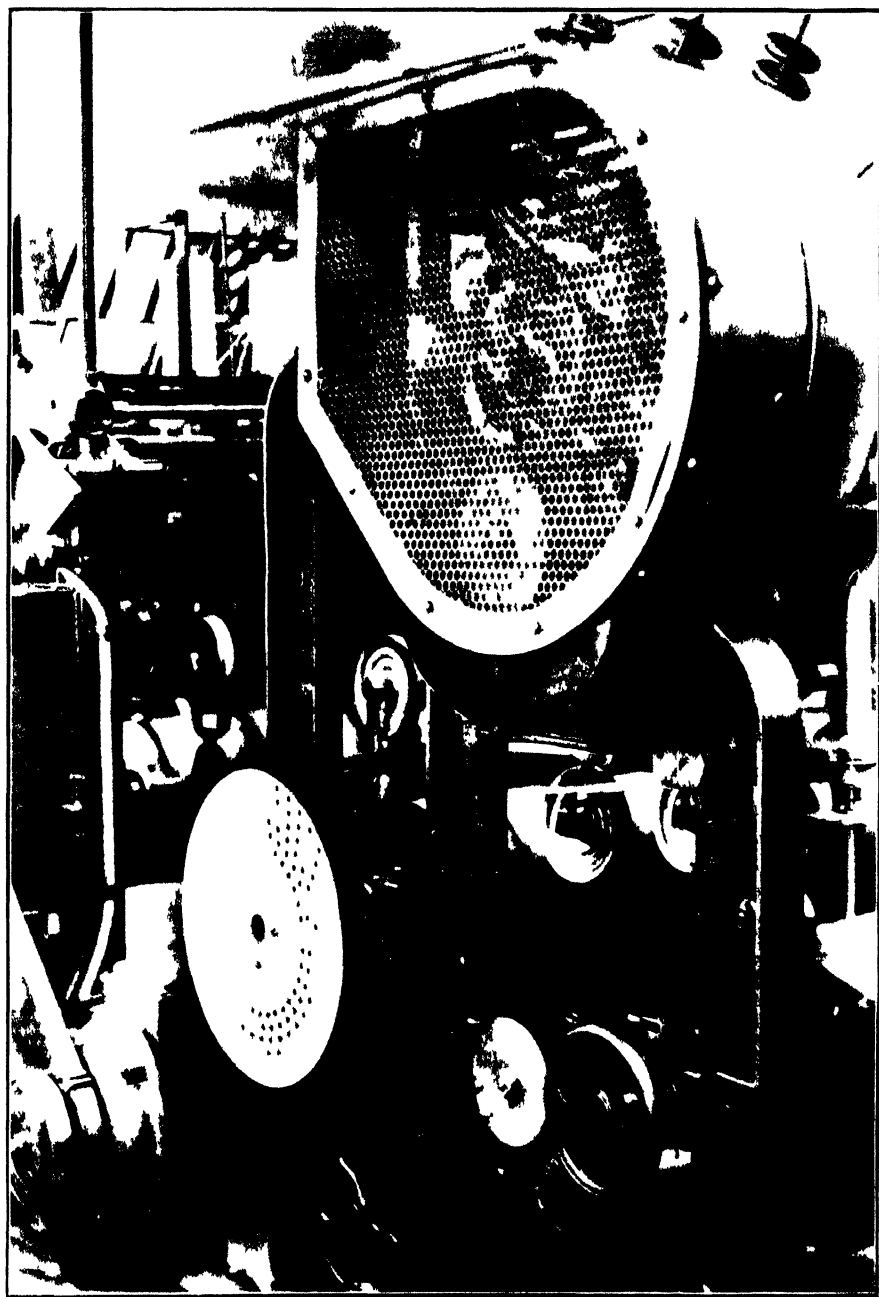
P=number of dots in the circle being observed,

N=number of dots in that circle passing a fixed point per minute,

$$\text{then} \quad B = \frac{1}{\theta} \left[PS - (\pm N) \right]$$

where θ is a whole number, and the +ve sign is taken when the apparent direction of motion of the dots is the same as the actual direction of motion of the disc (see Appendix).

Thus it is possible to make two separate readings of the spindle speed, by measuring the speeds of the dots past a fixed point on two adjacent rings. Actually it is found easier in practice to fix the eye on one particular dot and measure the time taken for it to travel round the circumference a given number of times. Knowing the number of dots in the circle, N can then be calculated.



The curve reproduced in Fig. 2 shows an interesting set of results taken during the spinning of some 1/24's 56's quality, with a calculated twist of 9.1 turns per inch. It shows the difference in speed between the right-hand and left-hand bobbins of a pair during the progress of a doff, first demonstrated by Stevenson³, and also the relation between the spindle speed and the balloon speed representing the amount of yarn wound on to the bobbin.

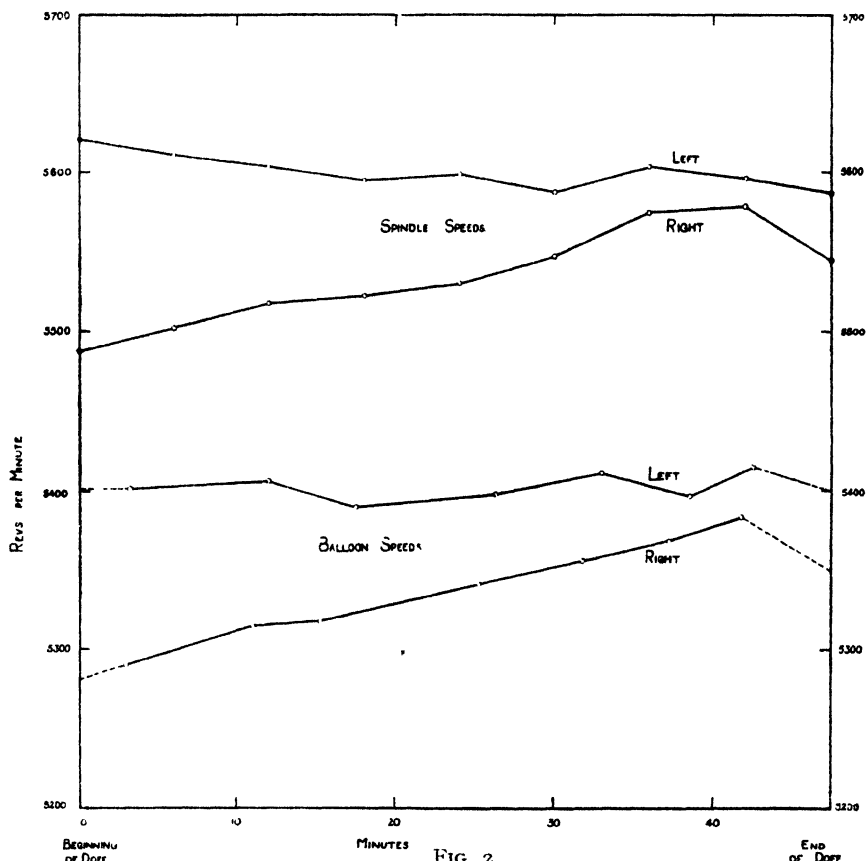


FIG 2

In this frame the lead on tape from the cylinder to the right-hand bobbin is bearing on the bottom flange of the whorle at the start and exerting a slight braking action. As the spinning proceeds the speed gradually increases as this braking is decreased, until it reaches a maximum just before the end, when the lead on tape is practically horizontal. The sudden drop at the end is due to the tape beginning to bear on the top flange of the whorle and again acting as a brake.

The speed of the left-hand bobbin is, of course, much more constant, since it always receives the tape horizontally from the right-hand bobbin. The slight decrease in speed with time is probably due to the gradual rise of the tape on to the crown of the whorle.

The mean difference between the spindle speed and the balloon speed in each case is about 195 r.p.m. This represents a "slip" due to winding on of 3.5%. The speed of the front roller in this case was 50.5 r.p.m., and its diameter 4 in., so that we have approximately—

Length of yarn wound on to bobbin for one revolution of balloon

$$= \frac{50.5 \times \pi \times 4}{195} \text{ in.}$$

giving an average "bobbin" diameter of $\frac{50.5 \times \pi \times 4}{195 \times \pi} = 1.035$ in.
which agrees with actual measurements.

The extreme difference between the maximum and minimum readings of balloon speeds is 135 r.p.m., representing a possible extreme variation in twist of 2.4% or about 0.2 turns per inch, which is really very small. The mean variation, of course, will be much smaller than this.

The following is a table showing the relation between "calculated" twist and twist as measured above from the mean balloon speed during a doff, for a range of twists on the same yarn.

Twist Wheel	"Calculated" Twist in Turns per Inch. Gauge Point 426	Measured Twist in Turns per Inch	% Slip
25	17.0	16.1	5.3
29	14.7	13.8	6.1
33	12.9	12.0	7.0
39	10.9	10.2	6.4
47	9.1	8.5	6.6
59	7.2	6.7	7.0
65	6.6	6.1	7.6

The percentage slip tends to increase with increasing twist, but the difference is not very marked. In any case it is difficult to adjust the lifter motion to give exactly the same amount of yarn on the bobbin for each twist.

The figures for the 47 wheel show a total slip of 6.6%, and as 3.5% is due to winding on, the remainder can be made up of either of the three causes (a), (b), or (c) enumerated in the second paragraph. The errors due to (a) and (b) can be made very small by accurate measurement, and the main part of the difference will be due to (c), which can be accounted for, as we have seen by the braking action of the tape on the flanges of the whorle.

From a practical point of view it is obvious that the ordinary "calculated" twist of the worsted spinner can be considerably higher than the actual value. The error will vary of course with the count and twist and the quality of the yarn, and also with the frame itself, but will in most cases be at least 5%.

Thanks are due to Mr. R. Ickringill and Mr. E. E. Marshall, who have helped considerably in the development of the method and in its application to a number of research problems.

APPENDIX

$$\text{DERIVATION OF FORMULA } B = \frac{1}{\theta} \left[PS - (\pm N) \right]$$

Let the stroboscope be synchronised with a bobbin rotating at speed B r.p.m. Then if S=cylinder speed

$$B = gS \quad \dots \dots \dots (I)$$

where g is a term slightly less than the calculated ratio of whorle to cylinder speeds.

From Equation I the time elapsing between two flashes of stroboscope $= \frac{1}{gS}$ min.

As any circle on the disc, say the P-circle, is rotating at a speed S r.p.m., each dot on the circle is completing an angle $2\pi S$ radians per min. Therefore,

in the time $\frac{1}{gS}$ min. elapsing between two flashes, a dot on the P-circle will have moved through an angle $\frac{2\pi S}{gS} = \frac{2\pi}{g}$ radians. Also, the angular distance between two consecutive dots on P-circle $= \frac{2\pi}{P}$ radians.

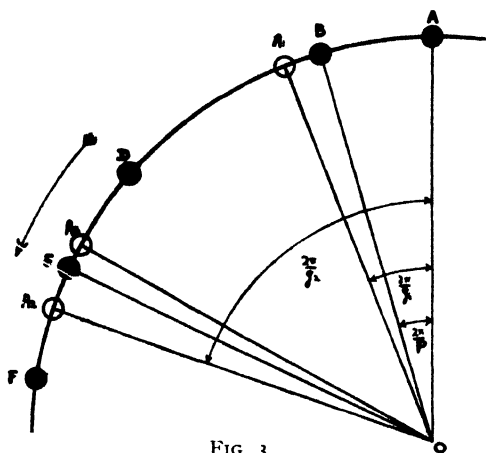


FIG. 3

In Fig. 3, suppose the black dots represent the P-circle in the position observed with zero flash of the stroboscope. Then, for a particular value g_1 of g , the dot A will appear in the position A_1 at the next flash of the stroboscope. But, as all the dots are similar, the dot will appear to have moved from B to A_1 and the angular displacement in time $\frac{1}{gS}$ min. will be $\left(\frac{2\pi}{g_1} - \frac{2\pi}{P}\right)$ radians. It will be obvious that, as the spindle speed increases, the position of A_1 at the second flash may be past B, C, D, E, etc. and

the apparent angular movement in time $\frac{1}{gS}$ min., will then be $2\pi \left(\frac{1}{g} - \frac{\theta}{P}\right)$ where θ = number of dots passed from the original position A. Thus, at A_2 , $\theta=4$. Then, the dots will appear to be rotating at a speed

$$\begin{aligned} & \pm 2\pi \left(\frac{1}{g} - \frac{\theta}{P}\right) \times gS \text{ radians per min.,} \\ & = \pm gS \left(\frac{1}{g} - \frac{\theta}{P}\right) \text{ r.p.m.} \dots\dots\dots (II) \end{aligned}$$

If the dot be in the position A_3 on the second flash, it will then appear to have moved in the negative direction through an angle EOA_3 ; i.e. $\frac{\theta}{P} > \frac{1}{g}$. Hence the \pm sign in Equation II.

From Equation II the apparent number of dots passing a fixed radius per min. $= \pm N = gS \left(\frac{1}{g} - \frac{\theta}{P}\right) \times P = PS - \theta gS$.

But $B = gS$

$$\therefore \pm N = PS - \theta B$$

$$\text{or } B = \frac{1}{\theta} [PS - (\pm N)]$$

θ can be determined practically from an evaluation of the fraction $\frac{PS}{B_1}$ where B_1 is the calculated whole speed. θ is then the next whole number above this figure.

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23—THE RATE OF COTTON ABSORPTION BY CARD CYLINDER WIRE, AND ITS EFFECTS ON SLIVER AND WASTES

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SUMMARY

This paper presents an analysis of the effects of varying the period (subsequently referred to as the working period) between successive strippings of a card, and deals essentially with (a) the rate of cotton absorption by the card cylinder wire, and (b) the effects thereof on sliver and wastes.

The tests were performed under both laboratory and mill conditions; the laboratory tests were conducted on a mixing of American and Egyptian cottons whose mean fibre length was 24.0 mm. and most frequent length 25.9 mm., and the mill tests on an American cotton with mean and most frequent lengths of 20.2 and 24.1 mm. respectively. The procedure adopted was to strip out the card after various periods of working, collect and weigh the strips, taker-in fly, flat wastes, and sliver, and express the results in terms of input percentages. The flat strips and sliver were tested for regularity.

The results of the investigations may be summarised as follows—

- (a) After stripping, a period of 20 to 25 minutes is taken for the rate of absorption by the cylinder to become reasonably steady (*i.e.* for the cylinder wire to become loaded).
- (b) The highest rate of cotton absorption by the card cylinder occurs on the resumption of carding after stripping, and the lowest rate just before stripping; the rate of absorption curve is approximately hyperbolic.

During the period of loading, a high proportion of good cotton is absorbed by the cylinder and there is little change in the constitution and appearance of the strips; the weight per yard of the sliver increases steadily; the total waste percentage rapidly decreases.

After the period of loading, the cylinder strip contains more short fibre and impurity; the sliver weight per yard becomes approximately steady, and the flat strip weight increases at a slow rate; the total waste percentage shows a steady decline.

TEST DETAILS

Particulars of the cottons used and the carding conditions for the two series of tests are given below.

Cottons used

SERIES A

Mixing of American and Egyptian cottons (in equal amounts) with mean staple length of 24.0 mm. and a most frequent length of 25.9 mm.

Sorter trace of mixing.

SERIES B

American cotton with mean staple length of 20.2 mm. and most frequent length of 24.1 mm.

Sorter trace of bale cotton.

Card particulars

					SERIES A	SERIES B
Lap weight per yard	...	...	...	...	11½ oz.	17 oz.
Rate of feeding	...	...	...	...	8.8 in/min.	14.85 in/min.
Taker-in speed	...	...	...	...	384 r.p.m.	480 r.p.m.
Cylinder speed	...	...	...	...	162 r.p.m.	196 r.p.m.
Doffer speed	...	...	...	...	11 r.p.m.	16.75 r.p.m.
Flat speed	...	...	...	...	3.5 in/min	2.125 in/min.
Settings—						
Feed plate—Taker-in	...	...	...	...	10's	5's
Taker-in—Cylinder	...	...	...	...	7's	5's
Flats—Cylinder	...	...	...	...	10's	10's-8's
Doffer—Cylinder	...	...	...	...	5's	5's
Points/sq. inch—						
Taker-in	...	...	...	...	36	36
Cylinder	...	...	...	...	450	500
Flats	...	...	...	...	550	500
Doffer	...	...	...	...	575	550
Card wire	...	...	...	...	Standard type wire was used in both cases, the inclinations on the cylinder and doffer being 80 and 70 degrees respectively, the knee angles being 140 degrees	
Sliver weight	...	...	...	...	33 grains/yd	67 grains/yd
Production	...	...	...	...	7.3 lb/hr	22.7 lb/hr.

The procedure adopted was to strip out the card after each period shown in Tables I (A and B), collect and weigh the strips, taker-in fly, flat wastes and sliver, and express the results as indicated. During the three hours period consecutive flat strips in groups of three were weighed and the results graphed in Fig. 2. From the weights of sliver produced from the successive periods the average rate of sliver output between these periods was determined (Tables II). Further, to investigate the sliver characters, the output resulting from the three hours period was wrapped in three yard lengths, and the irregularity $\frac{(M - S.M.)}{M} \%$ and percentage variation for the respective intervals were calculated.

To determine the change in the constitution of the cylinder strip during a normal working period, samples of this waste were analysed on the Baei sorter. In the following table the mean and most frequent lengths are given for the cylinder strips produced after various intervals. Fibre length distribution diagrams are shown in Fig. 3 of the cylinder strips produced after 5 minutes and 180 minutes respectively.

Cylinder strip production after—

		Scutcher lap	5 min.	10 min.	20 min.	90 min.	180 min
Mean length	...	mm.	20.1	20.0	20.0	19.7	18.2
Most frequent length	...	mm.	24.0	24.0	23.9	23.4	20.0

Table I—Series A

Period of Working (min.)	Fly (grams)	Flat Strip (grams)	Cylinder Strip (grams)	Sliver (grams)	Total Input* (grams)	Fly % Input	Flat Strip % Input	Cyl. Strip % Input	Total Waste % Input	Fly % Total Waste	Flat Strip % Total Waste	Cyl. Strip % Total Waste
1	67	36	701	441	1,245	5.4	2.9	56.3	64.6	8.3	4.5	87.2
2½	103	88	779	1,422	2,392	4.3	3.7	32.6	40.6	10.6	9.1	80.3
5	208	143	900	3,500	4,751	4.4	3.0	18.9	26.3	16.7	11.4	71.9
10	358	327	1,048	8,094	9,827	3.6	3.3	10.7	17.6	20.6	18.9	60.5
15	564	466	1,103	12,687	14,820	3.8	3.1	7.4	14.3	26.5	21.8	51.7
30	1,135	894	1,227	25,157	28,413	3.9	3.1	4.3	11.3	34.8	27.5	37.7
60	2,361	1,871	1,389	48,782	54,403	4.3	3.4	2.5	10.2	42.0	33.3	24.7
90	3,476	2,927	1,518	74,266	82,187	4.3	3.6	1.8	9.7	43.9	37.0	19.1
180	7,069	6,452	1,725	171,883	187,129	3.8	3.4	0.9	8.1	46.3	42.3	11.3

* Calculated, wastes plus sliver.

Table I—Series B

Period of Working (min.)	Fly (grams)	Flat Strip (grams)	Cylinder Strip (grams)	Doffer Strip (grams)	Sliver (grams)	Total Input* (grams)	Fly % Input	Flat Strip % Input	Cylinder Strip % Input	Doffer Strip % Input	Total Waste % Input	Fly % Total Waste	Cylinder Strip % Total Waste	Doffer Strip % Total Waste
2½	169	217	928	165	7,218	8,697	1.94	2.49	10.68	1.89	17.00	11.4	14.6	62.8
5	330	339	1,243	180	14,656	16,748	1.97	2.02	7.43	1.08	12.50	15.7	16.2	59.5
10	506	598	1,439	225	31,344	34,112	1.61	1.91	4.60	0.72	8.84	18.2	21.6	52.0
20	1,143	795	1,781	278	61,469	65,466	1.75	1.21	2.73	0.42	6.11	28.6	19.8	44.6
30	1,513	1,349	1,919	329	92,313	97,423	1.55	1.38	1.97	0.34	5.24	29.6	26.4	37.6
60	3,097	2,877	2,364	310	198,844	207,492	1.49	1.38	1.14	0.15	4.16	35.8	33.3	27.4
90	4,549	4,693	2,548	386	275,068	287,244	1.58	1.63	0.88	0.13	4.22	37.3	38.6	20.9
180	7,601	9,412	3,306	435	543,375	564,129	1.35	1.67	0.59	0.08	3.69	36.6	45.4	15.9

* Calculated, wastes plus sliver.

DISCUSSION OF RESULTS

In view of the exactness of the agreement between the results of the two series of tests, it has been considered advisable, for the sake of simplicity, to present the analysis of the results of one series only. For this purpose, series B has been chosen and will alone be referred to subsequently unless otherwise stated.

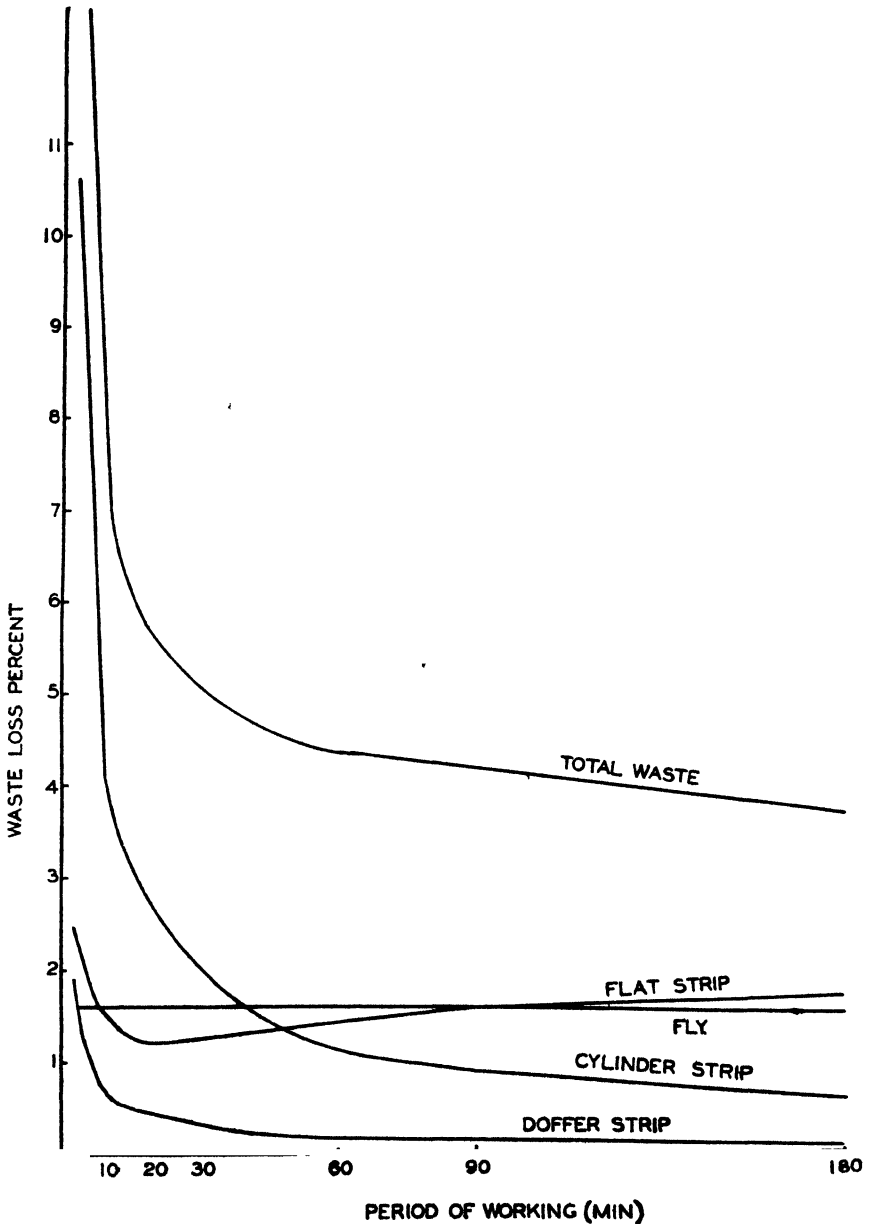


FIG. 1—Test Series B

Graph showing the waste losses (as a percentage of the input) for various working periods:

Total Waste

The total waste percentage throughout a normal working period is never constant. The character of the total waste percentage curve is such that during the early stages of the period the percentage shows a rapid decrease, but subsequently there is a slow diminution until the end of the period (see Fig. 1).

Taker-in Fly

This waste, indicated in Fig. 1, maintains, as might be expected, practically a constant percentage throughout any working period.

Cylinder Strip

To show the rate at which cotton is absorbed by the card cylinder, two quantities, the total cylinder strip (corrected, on the basis of the 180 min. period, for input variation) and the average rate of cotton absorption between the successive intervals have been evaluated below. The rate of absorption curve is shown in Fig. 2.

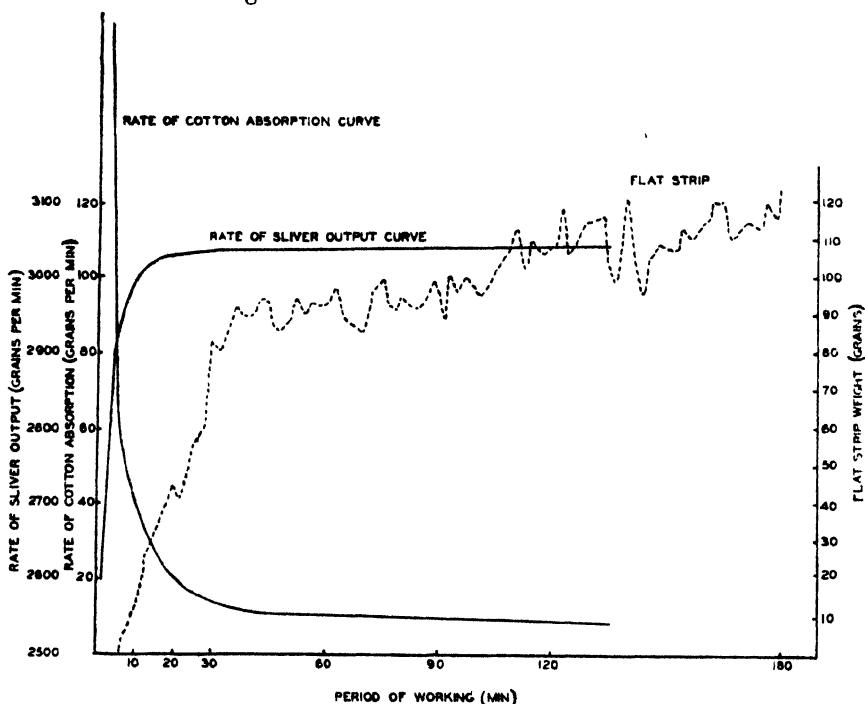


FIG. 2—Test Series B

It will be observed that (a) the cylinder strip increases in a characteristic manner throughout a full period of normal working, and (b) the highest rate of cotton absorption by the cylinder wire occurs on the resumption of carding after stripping, and the lowest rate just before stripping; the rate of absorption curve being approximately hyperbolic.

The absorption of cotton by the cylinder is influenced by the relative surface speeds of the main carding organs; the density of the fibrous film presented to the cylinder; the counts, condition and character of the cylinder wire; the type and condition of the cotton under treatment; and the setting of the various parts at which action occurs. But the results of tests conducted

Series A

Period... .. min.	1	2½	5	10	15	30	60	90	180
Cylinder strip (corrected) ... grains	588	844	982	1,106	1,160	1,349	1,590	1,722	1,725
Period... .. min.	0-1	1-2½	2½-5	5-10	10-15	15-30	30-60	60-90	90-180
Average rate of absorption by cylinder gr./min.	588	171	55	25	11	12	8	4	0.03

Series B

Period min.	2½	5	10	20	30	60	90	180
Cylinder strip (corrected) grains	838	1,162	1,321	1,708	1,849	2,145	2,499	3,306
Period min.	0-2½	2½-5	5-10	10-20	20-30	30-60	60-90	90-180
Average rate of absorption by cylinder ... gr./min.	335	109	32	38	14	10	12	9

under conditions differing in these respects indicate that the rate of the cotton absorption is always similar to that stated above.

Cotton may find its way into the cylinder wire by the interaction of the cylinder with the taker-in, flats and doffer, but to what extent each of these is responsible for the absorption of cotton by the cylinder it is impossible to state from the results of the present tests.

From the results shown in Tables I, A and B, and from examinations of the cylinder wire and strip, it may be concluded that for some time after stripping a considerable proportion of the cotton fed to the card is absorbed in filling up the interstices of the wires. This absorption continues to a decreasing extent until eventually the amount of the strip becomes approximately constant—a stage at which the sliver (Tables II) would appear to reach its normal hank or count. As the absorptive capacity of the cylinder decreases at a rather high rate, the sliver attains stability of count in a relatively short working period. The wire surface itself, is apparently incapable of giving adequate support to the fibres immediately after stripping, and, until a fibrous foundation has been formed, penetration of fibre into the cylinder wire is more or less inevitable.

In the series A investigation, the formation of this fibrous foundation took approximately 20 minutes, during which time the cylinder wire absorbed approximately 1,140 grains or 0.16 lb. of cotton. For the series B, where the card was working under mill conditions with an abnormally high production, this "loading period" was approximately 25 minutes, and the "loading value" 0.26 lb. These two factors, viz. the loading period and the loading value, vary considerably in practice, being dependent on the conditions already mentioned as influencing the absorption (page T216).

The variation in the cylinder strip percentage (Fig. 1) is most important in view of its influence on the total waste and on routine tests at the card, for it should be noted that the percentage is never constant and that, in the initial periods, it has an extremely high value. In the carrying out of accurate tests at any one card, therefore, it is essential that its characteristics, viz. its loading period and value, be thoroughly investigated and, as far as

possible, determined quantitatively for any particular set of conditions. This feature is mentioned by Turner¹ in the testing of standard Indian cottons, where the amount of cotton required to load the card wire is ascertained under given conditions.

Two important conclusions may be derived from the analyses (page T213) of the constitution of the cylinder strip during a normal working period, viz. (a) the constitution of the cylinder strip produced during the early stages (e.g. series B, 0–20 min.) of the working period is almost identical to that of the scutcher lap, and (b) subsequently, the mean and most frequent lengths decrease steadily. These conclusions are verified by the gradual deterioration in the colour and appearance of the strips after approximately 20 to 25 minutes working. Such results, together with the instability of the waste percentages during the loading period, would indicate—

- (i) that the removal of the loading cotton every stripping renders the operation uneconomical (for series B, the loss per card per year with cotton at 5.50 *d*/lb. and cylinder strip at 2.75 *d*/lb. amounts to approximately £2.4), and
- (ii) the desirability either of devising a method of stripping whereby the loss of the loading cotton can be obviated, or of preventing loading by suitable modification of the card wire.

Doffer Strip

The strip absorption by the doffer, as indicated by the curve in Fig. 1, is very similar to that shown by the cylinder. It appears as though the form of the curve is a characteristic of the wire, rather than of the actions performed by the cylinder and doffer respectively. The percentage of strip made by the doffer, however, is very small and of minor importance.

Flat Strip

During a normal three hours' working period of series B, consecutive strips in groups of three were weighed as produced and the results expressed graphically in Fig. 2. (Before the test commenced the card was completely free of cotton.)

The weight of the flat strips shows a rapid increase initially, then a gradual increase throughout the remainder of the working period. Further evidence of the increase in flat strip weight is shown in Fig. 1 where, however, the initial part of the curve differs from that in Fig. 2. This is due to the fact that in performing the tests given in Tables I, A and B, the flats were not run bare before the commencement of each test.

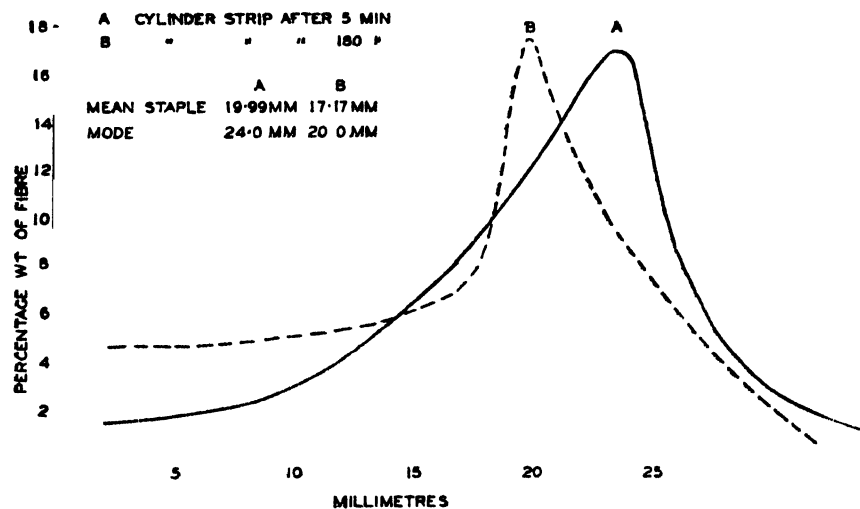
Baer sorter analyses of the flat strips produced after 10 and 180 minutes respectively, reveal no significant differences.

Sliver

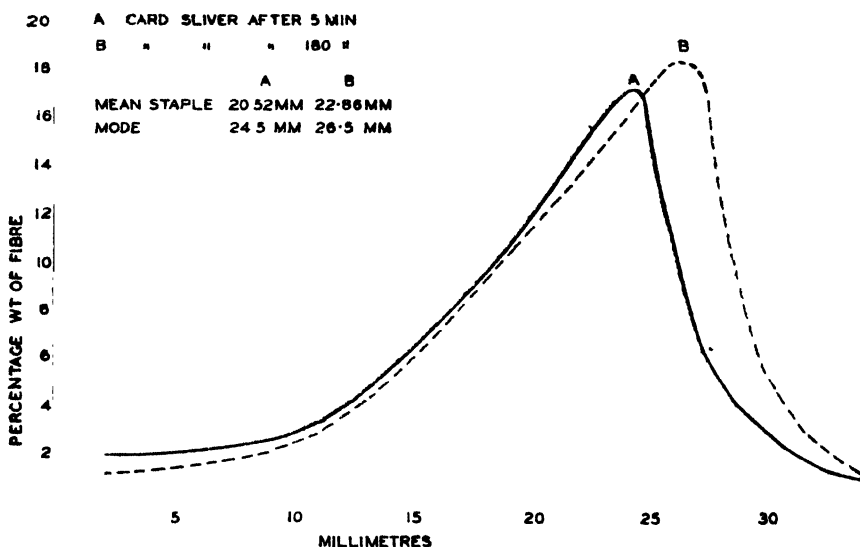
Fig. 1 shows that approximately 25 minutes are taken for the total waste percentage to approach a reasonable degree of stability. It is apparent also that the total waste does not attain absolute constancy and one might, therefore, expect a corresponding effect on the sliver. To investigate the sliver behaviour, it was decided to weigh the total sliver for each of the periods selected and determine the average rate of sliver output (corrected, on the basis of the 180 min. period, for input variation) between the respective periods (Tables II). A graphical representation of this rate is shown in Fig. 2. It would appear that during the loading period the sliver weight per yard is increasing at a rather high rate. Subsequently, there would appear to be a

tendency for the rate of output to increase slightly, but in view of the variability of the results, this must be regarded as inconclusive.

Further, to investigate the sliver characters, the output resulting from the three hours' period (series A) was wrapped, and the irregularity $\frac{(M-S.M.)}{M} \%$ and percentage variation for the respective intervals were calculated. The results show a tendency for more regular sliver towards the end of the loading period, although there is no significant difference in regularity afterwards.



Fibre Length distribution diagrams of Cylinder Strips.



Fibre Length distribution diagrams of Card Sliver.

TABLE II
Series A

Period ... min.	1	2½	5	10	15	30	60	90	180
Sliver produced (corrected) ... grains	366	1,550	3,815	8,580	13,322	27,421	55,826	84,531	171,883
Period ... min.	0-1	1-2½	2½-5	5-10	10-15	15-30	30-60	60-90	90-180
Average rate of sliver output gr./min.	366	789	906	953	948	939	947	957	970
Irregularity %	*	*	4.5	4.1	3.0	4.6	3.5	4.3	4.8
Variation ... %	*	*	25	15	11	23	20	27	29

* In view of the rapid increase in the sliver weight during these initial periods no values are given.

TABLE II
Series B

Period ... min.	2½	5	10	20	30	60	90	180
Sliver produced (corrected) ... grains	6,496	13,740	28,784	58,835	89,088	180,205	270,062	543,375
Period ... min.	0-2½	2½-5	5-10	10-20	20-30	30-60	60-90	90-180
Average rate sliver output gr./min.	2,598	2,897	3,009	3,005	3,025	3,037	2,995	3,037

The difference in the constitution of the sliver produced after 5 and 180 minutes respectively is indicated by the fibre length distribution diagrams shown in Fig. 3. The increase in the mean and most frequent lengths might be expected from the results of the waste analyses.

The contributor expresses his gratitude to Messrs. R. Greg & Co. Ltd., Reddish for permission to carry out the mill investigations, and to Mr. W. Miller for assistance in the practical work.

REFERENCE

- ¹ A. J. Turner Technological Reports on Standard Indian Cottons, 1927, 11

March Issue

- 15—**Influence of Ash Constituents on the Electrical Conduction of Cotton.** By A. C. Walker and M. H. Quell.
16—**Naturally-occurring Ash Constituents of Cotton.** By A. C. Walker and M. H. Quell.

April Issue

- 17—**Effect of Atmospheric Humidity and Temperature on the Relation between Moisture Content and Electrical Conductivity of Cotton.** By Albert C. Walker.

Attention is drawn to the fact that the work in connection with the above papers was carried out in the Bell Telephone Laboratories Inc., New York, U.S.A.

Editor

THE JOURNAL OF THE TEXTILE INSTITUTE TRANSACTIONS

24—PERIODIC VARIATIONS IN HANK PROCESSED YARN, AND THE PATTERNS PRODUCED BY THEM IN STOCKING FABRICS

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CONTENTS

- I—Introduction and Summary
- II The Visual Examination of the Yarn and the Measurement of Colour Periods
- III The Hank Periods
- IV Patterns formed in Stockings by Periodic Shade or Dyeing Variations in Yarns.

I - INTRODUCTION AND SUMMARY

A common defect in dyed cotton hosiery, particularly in dyed stockings made from mercerised yarns, consists in the occurrence of relatively short lengths of yarn dyed a different depth of shade, or a different colour, from the normal, and recurring regularly at constant intervals along the thread. The variation in shade is generally due to some lack of uniformity in the processing of the yarn, frequently in its mercerisation. The periods of recurrence, on the other hand, are generally characteristic of the form in which the yarn was wound for the particular stage of processing causing the lack of uniformity. The most usual form of package for the wet processing of yarn is the hank, and shade variations occurring in periods characteristic of the hank structure are very common defects. Different methods of hank winding, corresponding to different hank structures, are in use, but the bulk of the yarn prepared for hank mercerising or dyeing is wound, either on the so-called Grant reel, or on the Cross reel, system. These methods of winding differ from straight, or lea, reeling in so far as the yarn is subject to a rapid to-and-fro traversing motion as it is wound on to the swift, with the result that the hank is built up on a diamond network pattern. In their older meanings the terms "Grant reeling" and "Cross reeling" defined certain relations between the rate of revolution of the swift and the rate of traverse of the yarn, controlled by the ratio of the number of teeth in the swift wheel to that in the traversing wheel of the winding machinery. In conventional Grant reeling these numbers are 27 and 48 respectively, giving a ratio of about 1.78, whilst in conventional Cross reeling the wheels contain 28 and 58 teeth, giving a ratio of about 2.07. The original sense of these terms has to a certain extent been lost, and yarn described in the trade as Grant or Cross reeled may be wound with either of these ratios indiscriminately, or with neither; the combination of wheels with 28 and 48 teeth, corresponding to a ratio of 1.71, is not, for example, uncommon.

The foregoing explanation is necessitated by the fact that the lengths of the colour periods caused by a local irregularity in the processing of a hank are in some cases determined by the ratio of the swift to the traverse period on the winding machinery. The most usual ratio is still 27 to 48, and the term "Grant reeled" will be used throughout this paper to describe reeling with this particular ratio. The modifications necessitated by a different reeling ratio will be evident from the paper.

Much experience in the examination of dyed mercerised cotton stockings has shown that shade variations along the thread occurring with three different periods, all associated with the structure of the Grant reeled hank, are of somewhat common occurrence. These periods are (a) the hank circumference, (b) the hank circumference multiplied by the Grant reel ratio of 1.78, (c) 16 times the hank circumference. For the standard hank, these periods are 54, 96, and 864 inches respectively, but mercerised hanks are usually smaller in girth than the standard, and they may vary from about 51 to 54 inches in girth; this causes a proportional variation in the periods (a), (b), and (c). The 54-inch period is produced by a process variation that differentiates a portion of the hank across its whole width from the remainder of the hank. The 96-inch period results from a differentiation of the whole of one edge of a Grant reeled hank from the remainder of the yarn in it, whilst the differentiation of a random patch on the Grant reeled hank produces a complex pattern repeating along the thread at regular intervals equal to 16 hank circumferences.

If it is sufficiently pronounced, a periodic shade or dyeing variation in a hosiery yarn must always produce an unlevel appearance in the finished hosiery. If, on the other hand, the shade or dyeing difference is only slight, its effect in the knitted goods may be unimportant for practical purposes. In certain circumstances, however, the knitting of a yarn containing a periodic colour variation, actual or potential, has the effect of arranging the yarn in the most favourable way for displaying periodically recurring colour contrasts. Successive lengths of yarn of similar shade, or similar dyeing qualities, become grouped together in the fabric so that a striped pattern is produced, and when this happens very slight shade or dyeing differences produce an undesirable effect in the finished material. The formation of a pattern is dependent upon favourable ratios between the length of the colour period and the length of yarn in one course of knitting; in the case of irregularities caused during hank processing, these are closely related to the ratios between the periods of the winding machine and the period of the knitting machine. The commonest striped pattern in stockings knitted on a flat, or full fashioned, frame results from the combination of the 96-inch period, caused by an edge variation in a Grant reeled hank, with a knitting course of somewhat less than half this length.

It is of great practical importance to determine whether shade irregularity in a dyed stocking is due to a periodic variation, and to measure the length of the period when one is found to be present. If this should prove to be characteristic of the hank structure, as it does in the majority of cases, the problem of determining the cause of the irregularity is greatly simplified. The origin of the defect is restricted to processes in which the yarn was in hank form, and all earlier or subsequent processes, such as spinning, doubling, gassing, and knitting can be absolved from responsibility. When the shade

irregularity is such as to produce a well-defined pattern in the knitted goods, the colour variation is certainly periodic along the thread, and it merely remains to measure the period length. When the shade irregularity is such as to produce a random mottled effect in the knitted fabric the colour variation may still be periodic, the length of the course being unsuitable to the formation of a pattern.

The second part of this paper describes the apparatus that has been used for some years in the laboratories of the Shirley Institute to test the periodicity of a colour variation, to measure the period length, and to provide a permanent record of the shade levelness of a dyed yarn. The winding apparatus employed in this test is similar to that described recently for a similar purpose by Dr. Ing. G. Krauter, of the Deutschen Forschungsinstituts für Textilindustrie in Dresden (*Leipziger Monatschrift für Textil Industrie*, 1931, Vol. 46, p. 377).

The third part of the paper contains a description of the yarn periods produced by different local variations in hanks wound with a rapid traverse motion.

The fourth part deals with the relation between the nature of the pattern and the length of the period. This subject is capable of a simple generalised mathematical treatment, but it has been considered sufficient to give graphical illustrations of the two or three cases of chief importance in stocking fabrics made from hank-processed yarn.

II—THE VISUAL EXAMINATION OF THE YARN AND THE MEASUREMENT OF COLOUR PERIODS

A shade variation in a dyed yarn, unless it is very great, cannot be seen clearly by examination of a length of thread laid flat, much less can a periodic variation be detected and its period measured. In order to do this it is necessary to wrap the yarn into a pad, or to knit or weave it into a fabric, under conditions favourable to the formation of contrasting areas of different colours.

The apparatus used at this Institute is illustrated in Fig. 1a.

The steel rod A is about 6 inches long, and the exact diameter is not important, but should be about $\frac{5}{8}$ inch; it is convenient if the circumference is exactly 2 inches, corresponding to a diameter of 0.637 inch. The shaft of the rod is clamped into a bearing by means of the screw B, the rod can be rotated by the handle C, and the number of revolutions is recorded on the automatic counter D. Yarn to be examined, for example, withdrawn from a stocking, is wound through a spring tension device E on to the rod, starting from the end near the handle. The tension device is placed one-and-a-half to two yards from the rod, which is so arranged that the path of the yarn is not quite at right angles to the axis of the rod, but makes such an angle with it that there is always a slight pull on the yarn being wound, tending to drag it back along the rod in the direction of the handle, as illustrated in Fig. 1b. The effect of this drag is to pull every turn of the yarn tightly against the preceding turn, and by adjusting the position of the rod three or four times, a smooth and compact wrapping 5 or 6 inches long is readily obtained. It is important to secure as compact a wrapping as possible, as the detection of faint colour bands is rendered more difficult when the background can be seen showing through between individual turns of the yarn. Near the beginning

of the wrapping an ink mark is made with a pen on the yarn before it reaches the rod, and the reading of the revolution counter as this mark passes on to the rod is noted. A similar short ink mark is made on the yarn passing on to the rod at a point near the end of the wrapping, and the corresponding reading of the counter again noted; the exact length of yarn between the two ink marks can be calculated from the number of revolutions of the rod and its known circumference.

In Fig. 2a, which shows the rod covered with a typical wrapping from a defective stocking, the regularly alternating dark and light bands are clearly visible. In order to obtain a permanent record, and to facilitate the calculation of the period, the surface of the yarn is covered with a strip of adhesive (rubber) tape of the correct length and width exactly to encircle the wrapping. The rod with its adhesive covering is slightly warmed in an oven and well rolled on a flat surface to ensure adhesion of the yarn to the tape, which is then cut from the rod by a razor incision parallel to the axis of the rod at the junction of the two edges of the tape. A compact yarn pad held together by its tape backing is thus obtained, which is pressed flat between damp cloths with a hot iron, and stuck to a card for convenience in handling. Fig. 2b, c and d, show photographs of pads prepared in this way from faulty stockings in which regular systems of bands can be seen. In order to determine the period of the colour variation it is only necessary to place the yarn pad on a sheet of paper, and to trace pencil marks on the paper at the edge of the pad opposite the centre of each successive dark (or light) band. The average distance between successive marks is calculated from the pencil tracing, and the distance between the two ink marks on the pad is measured. The length of yarn between the ink marks is known, and therefore the length of yarn corresponding to the average distance between successive colour bands is easily calculated. This is the period of the colour variation. The examination of yarn pads made in the way described above provides an excellent general method for judging the shade levelness of yarns, or for determining the incidence of shade irregularities. It enables the period of the colour variations responsible for patterned defects to be determined, and it shows that in many dyed stockings of mottled appearance the defect is a periodic one in the yarn, though the course length is unfavourable for the formation of a pattern. The effect on the shade levelness of such treatments as stripping the original dye and redyeing, or stripping, remercerising and redyeing, is also most easily judged by carrying out these operations with small skeins of yarn which are finally wrapped into the form of flat yarn pads for comparison with the original. Two different yarns can also be best compared in shade or dyeing qualities by inserting them as alternating bands about an inch wide in yarn pads of this kind.

III—THE HANK PERIODS

When the results obtained from the examination of a large number of stockings are reviewed, it is found that with no more than a few exceptions the periods all fall in one of three groups. In the first group, the dark (or light) colour bands are regularly spaced at intervals which vary slightly in individual cases, but always fall within the limits 50 to 54 inches (Fig. 2b). The bands are also regularly spaced in the second group, but the interval is slightly less than twice the length of that characteristic of the first group; there is again a slight variation between individual cases, but the periods all fall within the limits 89 to 96 inches (Fig. 2c). In the third group, the bands, although

arranged according to a regular system, are not all equally spaced, and a number of bands at about the 50 to 54-inch interval characteristic of the first group may, for example, be followed by a number at about double, or a greater multiple of, this interval. The precise arrangement varies in individual cases, but the effect produced is frequently that of a series of first group bands, from which few or many have been omitted according to a regular plan of periodicity equal to 16 times the hank circumference; such systems of colour bands are described for convenience as the "interrupted periods" (Fig. 2d). It will be shown that the periods in all three groups are characteristic of the Grant reeled hank structure.

A variation of any kind that produces a locally defective patch the full width of the hank must affect every turn of yarn in it, and the defect produced by the variation must recur along the thread at regular intervals equal to the hank circumference. Wet-processed hanks are not often finished to the full standard 54-inch circumference, and mercerised hanks, in particular, cover a girth range from about 50 to 54 inches. The stocking periods in the first group (50 to 54 inches) are evidently the circumferences of the processed hanks used in the manufacture of the material. They correspond to a period in the winding machinery, namely, the length of yarn wrapped in one revolution, or period, of the reel, slightly modified by the varying amount of shrinkage experienced in the subsequent wet process.

The winding machinery has, however, another period, namely, that of the traversing yarn guide. Much of the hank yarn used for hosiery is Grant reeled, and in this form of reeling the yarn makes nine complete traverses, backward and forward across the hank width, during 16 revolutions of the reel. The length of yarn passing through the guide in one complete to-and-fro traverse for a reel of 54-inches circumference is, therefore $54 \times 16/9$, or 96 inches. Hence at regular intervals of 96 inches the thread arrives at one and the same edge of the hank, and a variation of any kind that produces a defective patch of yarn round the whole of one edge of a Grant reeled hank must result in a regularly recurrent defect at intervals of 96 inches. It has been seen that this length is a constant fraction ($16/9$) of the hank circumference, and if the latter varies from 50 to 54 inches owing to variations in shrinkage during processing, the former must vary from about 89 to 96 inches. The stocking periods in the second group clearly correspond to the traverse period of the yarn in the processed hanks used for the manufacture of the material, just as those in the first group correspond to the period, or revolution, of the reel.

In the conventional Cross reeled hank the yarn guide makes 14 complete traverses during 29 revolutions of the reel, giving a yarn traverse period of 104 to 112 inches. Such a hank with a defective patch round the whole of one edge would result in a colour variation along the thread recurring with this period, but it is not often observed in practice. A hank reeled with wheels containing 48 and 28 teeth, and containing a defective edge, would result in yarn periods from about 86 to 93 inches, and these would often be indistinguishable from the corresponding periods in the conventional Grant-reeled hank.

It is to be observed that a defective patch round the whole circumference of a Grant reeled hank, *but not at its edge*, would produce yarn periods of 45-49 inches, but these have never yet been encountered at this Institute.

As a result of the method of traversing adopted in Grant reeling, the thread is laid down obliquely around the staves of the reel, and the crossing of the oblique threads produces a hank with the characteristic network of diamond-shaped meshes. Suppose that the leading yarn end is fastened to a certain point on one of the staves of the reel, and that winding is started and again stopped after the reel has made exactly 16 revolutions. The last fraction of an inch of yarn to be wound on the reel will occupy a position corresponding exactly to the starting point with respect to the circumference of the hank, because the reel has made an exact whole number of revolutions. During the winding, the traversing guide has also made an exact whole number of traverses (9), and the last yarn to be wound will also correspond in position to the starting point with respect to the width of the hank. The last short length of yarn wound on the reel before it stopped must, therefore, be situated exactly above the starting point. It follows that the diamond network is completed in 16 reel revolutions, and the whole of the hank must build itself up on top of the unit pattern laid down during these first 16 revolutions. The length of yarn wound during this time for a 54-inch hank is 16×54 inches, and this is yet a third period associated with the mechanism of Grant reeling.

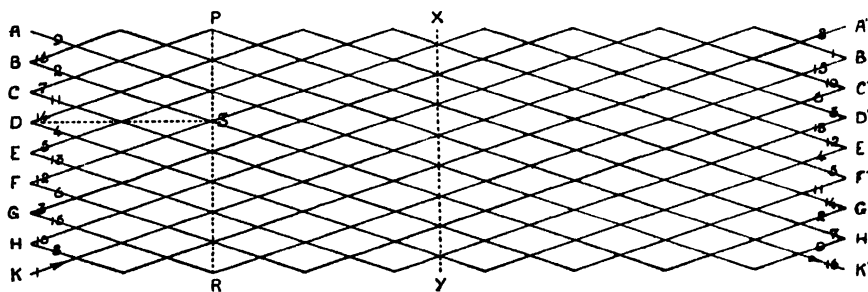


FIG. 3

Fig. 3 is a diagrammatic representation of the unit pattern of Grant reeled hanks, that is, of 16 consecutive hank rounds. The hank is supposed to be cut across its width and laid out flat, the edges AA', KK', being, therefore, equal to the hank circumference (54 inches), and the sides AK, A'K', to its width or gauge (3 to 4 inches); in order to reconstruct the original hank, the figures must be folded on the line XY so that the points A, B, C, . . . K become identical with the points A', B', C' . . . K'. The diagram has been simplified by assuming that the traversing yarn guide moves at constant speed, reversing instantaneously at the end of each stroke (half period), whilst in practice this guide generally moves with a simple harmonic motion, its speed increasing from the beginning of the stroke to a maximum at the middle and falling off again to the end of the stroke. The threads should, therefore, be represented in the figure by slightly curved, instead of straight lines, and the meshes should diminish progressively in width (direction AK) on moving from the middle to either edge AA' or KK'; in the same fixed fraction of the hank width there should, in fact, be much less total yarn near the middle than near either edge. The simplification of the diagram does not, however, affect the considerations that follow.

In the diagram, successive hank rounds are numbered in order, and it can be seen, for example, that the first round starts at the point K, whilst the sixteenth round ends at the point K', which, in the uncut hank, is immediately

on top of the point K; the seventeenth round, therefore, falls on top of the first, as also must the thirty-third, the forty-ninth, etc. If a variation of any kind produces a defective area such as APRK on the hank, it will result in a 54-inch yarn period; if an area such as ADD'A' is affected a 96-inch yarn period will result. These are the two cases already discussed. Suppose, however, that the defective area is neither a complete width over a part of the length, nor a complete length over a part of the width, but a patch such as DSRK in the figure. From an examination of the diagram it can be confirmed that the hank rounds falling partly within this area are numbered as follows—

1, 3, 4, 5, 6, 8, 10, 11, 12, 13, 15 (17, 19, etc.)

Five hank rounds, namely, the 2nd, 7th, 9th, 14th, and 16th miss the area entirely. If the hank circumference is designated by H, the defect produced by the affected patch will, therefore, recur along the thread, for example, as bands in the wrapping, at roughly the following intervals—

2H, H, H, H, 2H, 2H, H, H, H, 2H, 2H,

and this arrangement of bands will repeat itself every 16 hank rounds. The period for a hank of 54-inch circumference is then 16×54 inches, since a patch of any shape on the hank must repeat itself at this interval, but within the period there are several alternations of good and defective places in the yarn, the distance between successive repeats of good (or defective) places being sometimes roughly 54 inches and sometime roughly a multiple of this. The lengths of the defective yarn stretches vary, and when the area of the patch on the hank is large the distance between the centres of successive defective lengths may differ considerably from the hank circumference, or a multiple of it. This arrangement of colour bands is characteristic of the yarn pads obtained from some defective dyed stockings, and called earlier the "interrupted periods" of the third group. It is now seen to be a simple consequence of a random defective patch on a Grant reeled hank. The "interruption" is shown to be due to the fact that certain hank rounds do not cross the defective patch, whilst the regular plan controlling the interruption is a consequence of building the hank in superimposed layers containing 16 turns of yarn. The precise way in which the interruption occurs depends upon the size and shape of the defective patch, and it is instructive to work out, by means of the diagram in Fig. 3, the repeating patterns that result from the differentiation of areas of various sizes and shapes.

In the above discussion it is assumed that the threads in the hank retain substantially the same positions relative to one another during handling and processing as they occupied when they were laid down on the reel during winding. This condition is to some extent ensured by the tie-bands, but a certain amount of disturbance of the hank structure is inevitable, and must affect the exact arrangement of the colour bands.

For a hank reeled with wheels containing 58 and 28 teeth (29 to 14), the unit diamond pattern is only completed after 29 revolutions of the swift, and a random defective patch on such a hank would produce, in a yarn pad, an interrupted system of colour bands with a period of 29 times the hank circumference; this period has not so far been encountered in dyed stockings. Similarly, for a hank reeled with wheels containing 48 and 28 teeth (12 to 7), the period would be 12 times the hank circumference, and this has occasionally been observed in defective dyed mercerised stockings. The interrupted period illustrated by the photograph of a yarn pad in Fig. 2d is an example of this. The light bands in this wrapping are numbered 1 to 10, and the

length of yarn between bands 2 and 3 is roughly equal to the hank circumference. If this is again called H , simple inspection of the photograph shows that the intervals between successive bands are—

$$2H, H, 2H, 2H, 3H, 2H \quad | \quad 2H, H, 2H$$

In this series, the arrangement of colour bands begins to repeat itself where the line is drawn, a fact that was confirmed on much longer wrappings containing many more bands, and the length of yarn in the period is, therefore, 12 hank circumferences. This pattern cannot occur in a Grant reeled hank, for which the corresponding period is 16 circumferences. The conventional Grant reeling (48 and 27 teeth) differs by only one tooth in one wheel from a reeling system with 48 and 28 teeth, but the effect of this change upon the fundamental diamond pattern of the hank is sufficient to distinguish at any subsequent time between yarns reeled with the two slightly different ratios, provided the yarn, whilst yet in hank form, received some variable treatment differentiating the dyeing properties of a random patch on its circumference from those of the remainder of the hank.

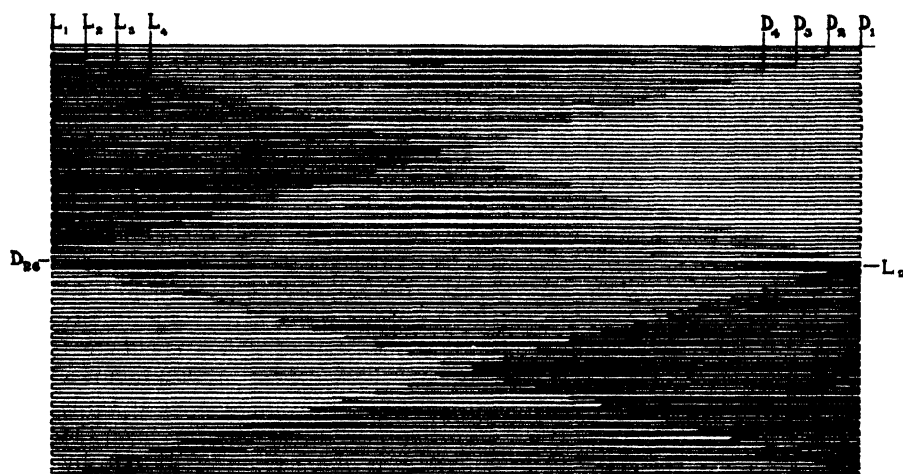


FIG. 4

IV—PATTERNS FORMED IN STOCKINGS BY PERIODIC SHADE OR DYEING VARIATIONS IN YARNS

When the ratio between the length of yarn in the width of the material, and the period length of any recurrent variation affecting the appearance of the yarn, approaches certain simple values, a more or less bold pattern is built up in the fabric. This is a fairly well-recognised effect, which may have important consequences in the construction of woven fabrics as well as in that of hosiery. It will be sufficient to consider the two cases of chief importance in the manufacture of stockings on a flat frame, namely, those in which the ratio of the colour period to the length of yarn in one course of knitting approaches values of 2 and 1. It will be necessary to refer frequently to this ratio, and as a matter of convenience it will be called the "pattern ratio."

The former case (pattern ratio near to 2) is illustrated diagrammatically in Fig. 4 in which the horizontal lines represent the courses of knitting in a fabric (naturally they do not in practice follow a straight path), and the periodic

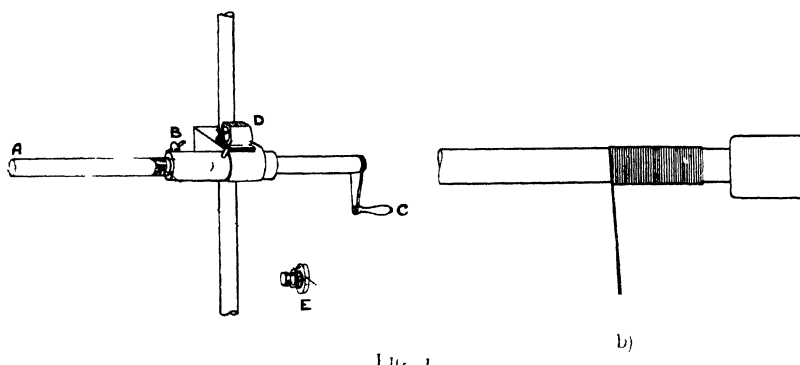


FIG. 1

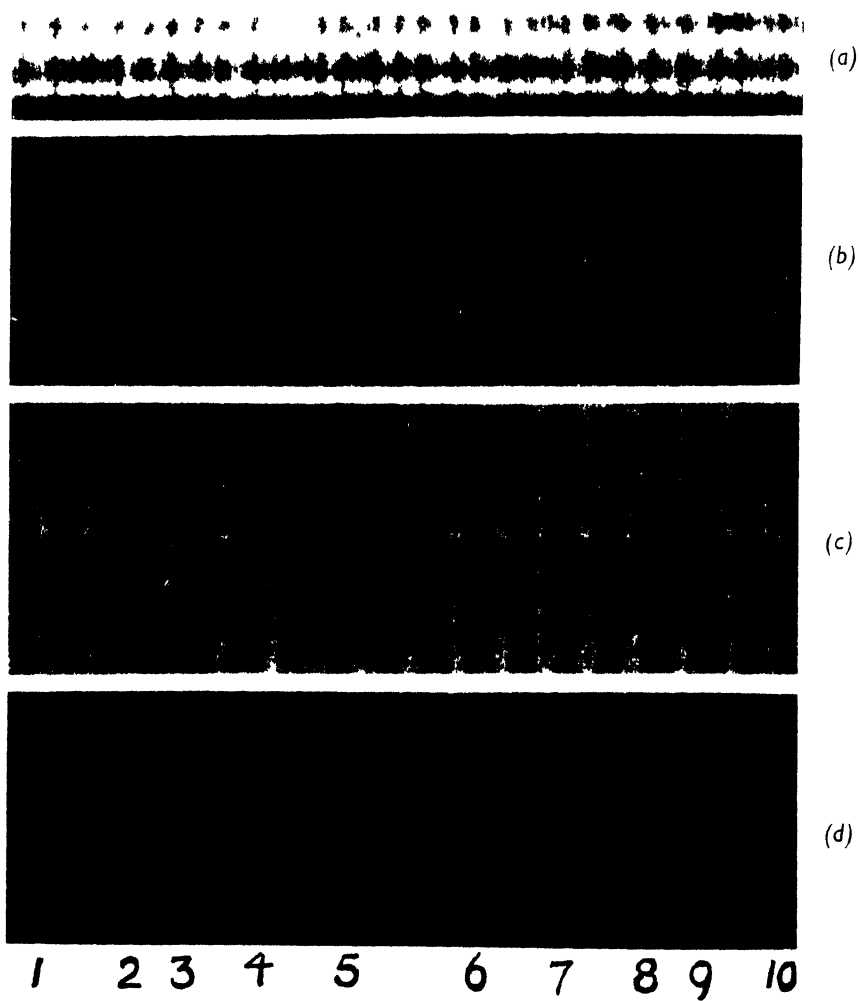


FIG. 2

Wrappings of yarn from dyed mercerised stockings showing periodic colour variations.

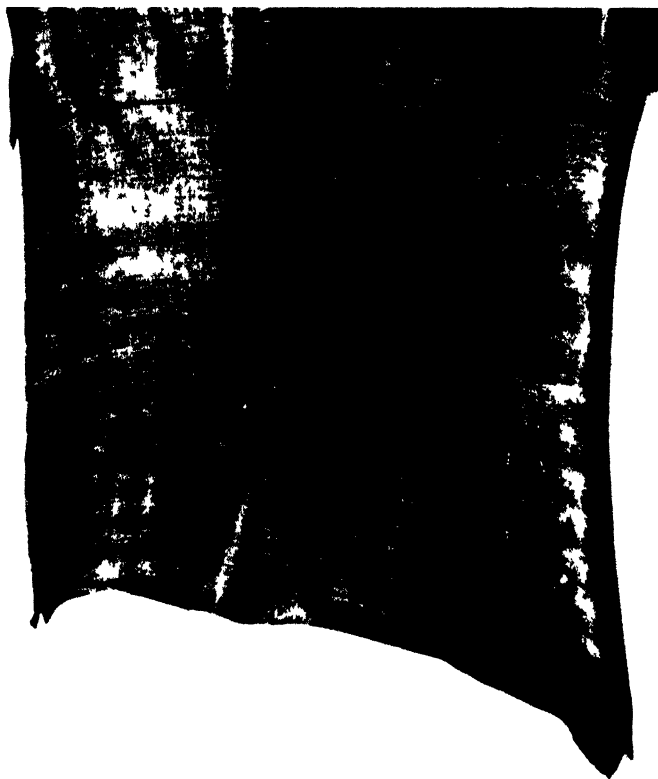


FIG. 5
Upper part of folded stocking showing colour bars

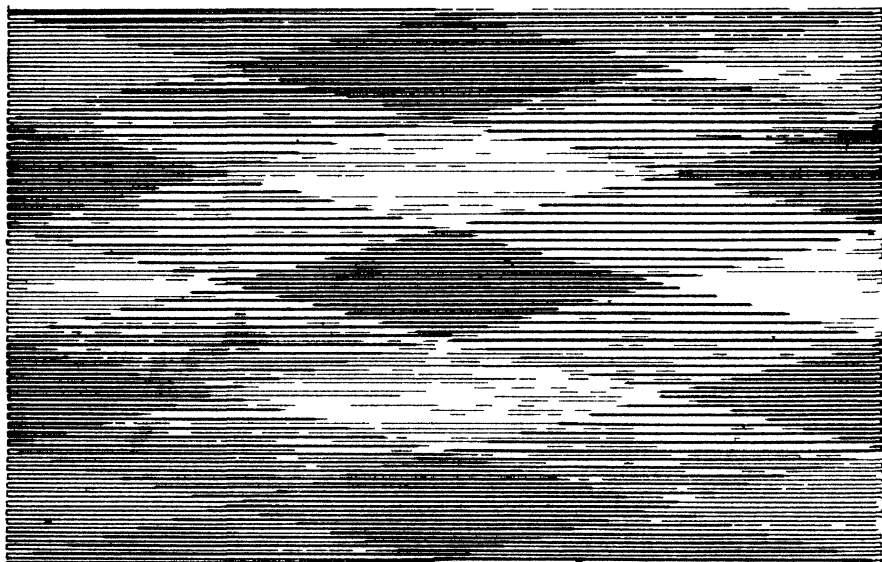


FIG. 6

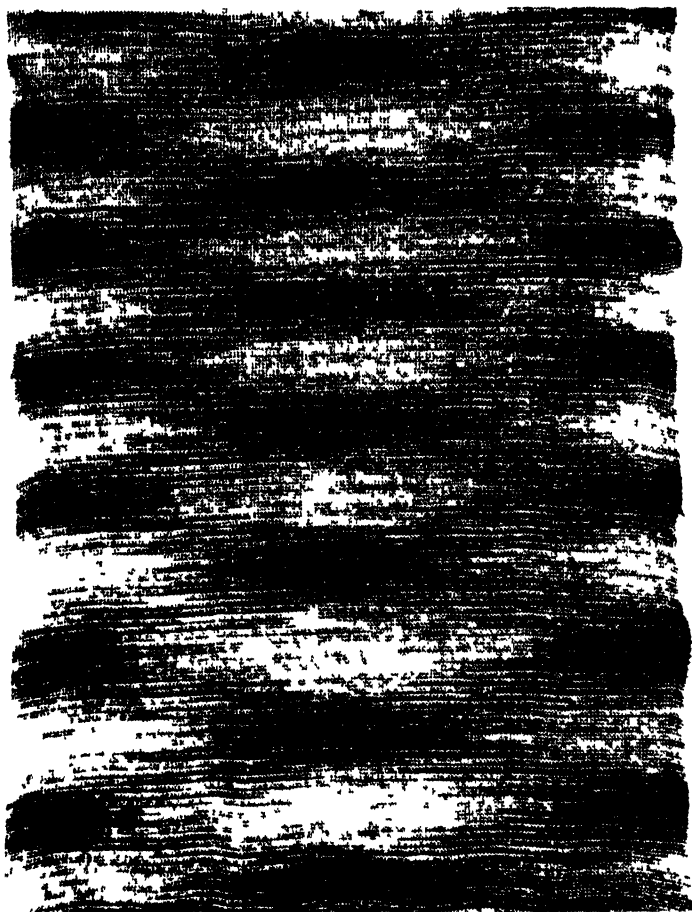


FIG 7

Dyed knitted fabric with pattern ratio near to unity

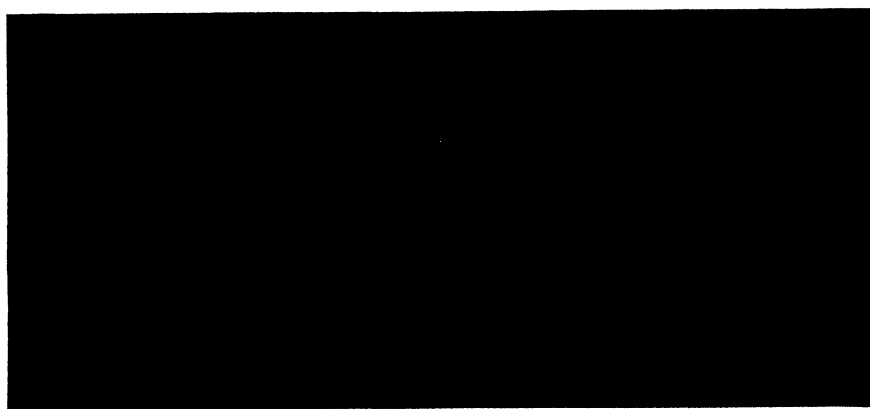


FIG 8

Welt of a dyed stocking showing the effect of a short periodically recurrent dark length of yarn

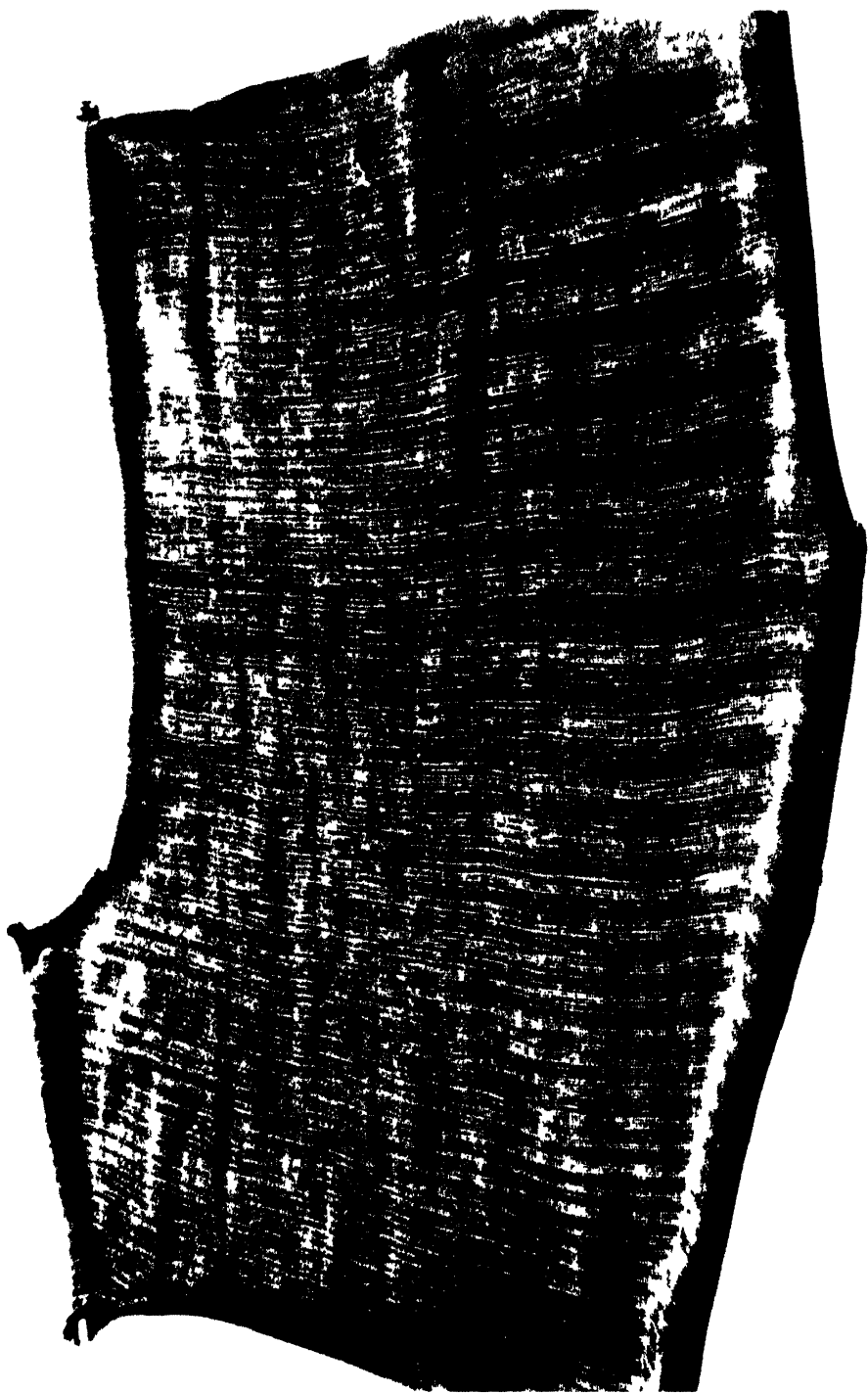


FIG. 9

The lower part of the dyed stocking shown in Fig. 5

colour variation in the yarn is represented by regular alternations of light and dark line. The diagram is intended to illustrate the case in which the length of yarn in the course is 100 inches and the period of the colour variation is 204 inches, the pattern ratio thus being 2.04; the 204 inches of yarn comprising the period consists of 100 inches of dark, and 104 inches of light yarn. If the courses are followed in the direction of the arrow, it will be seen that the starting points D_1, D_2 , etc. of the dark stretches move in a diagonal line from right to left across the fabric, the starting points L_1, L_2 , etc. of the light stretches in a similar diagonal line from left to right. Within 52 courses of knitting these two lines $D_1, D_2 \dots D_{26}$ and $L_1, L_2 \dots L_{26}$ extend from one edge of the fabric to the other, and they divide the area covered into four sections. The whole of the yarn in the left-hand section is composed of dark yarn, that in the right-hand section wholly of light yarn, whilst in the upper and lower sections dark and light yarn alternate regularly on successive courses. It will be seen that as the knitting continues past the 52nd course (D_{26}, L_{26}), a similar pattern is built up, the wholly dark and wholly light sections merely interchanging their positions, whilst a uniform distribution of dark and light yarn persists in the intermediate diamond-shaped areas.

The design formed by the ordered arrangement of dark and light yarn in Fig. 4 will evidently be produced whenever the pattern ratio is 2.04, the actual values of the colour period and length of knitting course being immaterial. Identically the same design must result from a pattern ratio of 1.96, but if the ratio is slowly altered in either direction away from the exact value of 2, the slope of the diagonal lines $D_1, D_2 \dots D_{26}$, and $L_1, L_2 \dots L_{26}$ changes very rapidly in such a way that the areas of individual wholly dark, wholly light, and uniformly mixed, sections rapidly diminish. The pattern then becomes much less striking to the eye, and the condition necessary to produce a bold pattern of the type shown in Fig. 4 is therefore that the pattern ratio shall be near the value 2.

The scale used in the drawing of Fig. 4 is such that the width of the knitted fabric is represented as two hundred times the distance between successive courses. For the construction of the average full-fashioned stocking the width of the fabric is about five hundred times the distance between successive courses. In order to represent this relation on a true scale, the drawing should therefore be compressed to two-fifths of its present length without alteration in its width, and the sections of wholly dark and wholly light yarns that start from the edge of the fabric then become relatively narrow stripes tapering towards the middle of the fabric. This is a very common pattern in defective stockings knitted from mercerised yarn, and a good example is illustrated in the photograph of Fig. 5, which shows the upper part of a dyed stocking opened up the back seam and laid flat. The most striking visual feature of the pattern is generally the regular alternation of light and dark areas at each edge of the fabric, that is, at the seam of the stocking.

The other case of immediate interest is that in which the pattern ratio is near to 1. In Fig. 6, which represents this case diagrammatically, the length of yarn in the course is 100 inches, the colour period 102 inches, composed of 50 inches of dark followed by 52 inches of light yarn, and the pattern ratio is 1.02. The pattern is again built up from a design of diamond and half-diamond shaped areas, consisting of wholly dark, wholly light, and uniformly mixed yarn. When the drawing in Fig. 6 is compressed in the direction of its

length, the visual effect is that of a series of stripes at each edge of the fabric, alternately dark and light, separated by a third series of longer alternating stripes down the middle of the fabric. A bold pattern of this type is only formed when the pattern ratio is near to 1, and an example is illustrated by the dyed knitted fabric photographed in Fig. 7. It will be necessary to refer frequently to the two patterns illustrated diagrammatically in Figs. 4 and 6, and they will be called for convenience the $b-b$ and the $b-B-b$ patterns respectively, where the symbol b denotes a bar or stripe at the edge of the fabric (a very elongated half diamond), and the symbol B a bar or stripe in the middle of the fabric (a very elongated whole diamond); the nomenclature thus indicates the sequence of stripes observed on passing from one edge of the fabric to the other.

The conspicuousness of the pattern depends upon three factors—(a) it is evidently affected by the absolute colour difference between dark and light yarn, which may be great or small; (b) it is affected by the proximity of the pattern ratio to values of 2 or 1; (c) it is also influenced by the ratio of the lengths of dark and light yarn within the period. The pattern is most striking, other things being equal, when the lengths of dark and light yarn are approximately equal. If there is a large discrepancy between these lengths, the solid dark or the solid light area is so reduced in size that the contrast may no longer be very striking to the eye. If, however, this unfavourable relation is counterbalanced by an increased absolute colour difference between dark and light yarn, the pattern may still be very prominent; but its true diamond formation is then displayed, and the visual result is not a barred or striped effect. The stocking fabric photographed in Fig. 8 is an example of a pattern ratio near to 1 in which the light yarn greatly preponderates over the dark, and the striking features are the large solid light diamonds and half-diamonds. The diagonal lines separating these are areas of mixed dark and light yarn, whilst the more intense dark spots at the intersections of the diagonals are the areas of wholly dark yarn.

It is now possible to consider the conditions under which the periodic shade or dyeing variations found in hank processed yarns may be visually accentuated by the separate massing of dark and light lengths into colour stripes. The length of yarn in a stocking course naturally varies, but in the legs of full fashioned hose (*i.e.* hose knitted on a flat frame) it generally lies between 35 and 45 inches. Values outside this range are sometimes found, and in all full-fashioned hose the course length is greater in the welt, and less in the ankle than in the leg. The first group of hank periods has been stated to vary from 50 to 54 inches. With the length of yarn per course from 35 to 45 inches, the pattern ratio can then vary from 1.11 (50/45) to 1.54 (54/35). This is not a very favourable range for the formation of a distinct pattern, only the extreme lower limit (1.11) being likely to show a pronounced pattern. A slightly greater length per course would give a pronounced $b-B-b$ pattern (for example, 50/48 equals 1.04), and this pattern has occasionally been observed in the welts of stockings, where the course length is greater than in the leg.

The general conclusion is, however, that periods of 50 to 54 inches will not often build up in normal stocking sizes to give pronounced patterns in the leg, and in fact such patterns are not common. In spite of this, faulty stockings in which the defect is caused by colour variations with a 50 to 54-inch period are frequent, but this is due to the fact that in such stockings the difference

in colour between "light" and "dark" yarn is so great that an unlevel appearance is produced in the fabric *even without the difference being accentuated by the contrast of solid light and dark areas*. A very slight difference in colour between the dark and light yarn within a 50 to 54-inch period would have a good chance of escaping notice in a stocking, because the construction of the fabric is unlikely to accentuate it strongly.

The hank periods in the second group fall within the range 89 to 96 inches, and, with the length of yarn per course equal to 35 to 45 inches, the pattern ratio covers the range 1.98 to 2.74. This is a much more favourable range for the formation of conspicuous patterns, since it includes the value 2 near which patterns of the $b-b$ type are formed. The photograph of the striped stocking in Fig. 5 has already been quoted as an example, and very many others have been encountered. Fig. 9 is a photograph of the lower part of the same stocking as that shown in Fig. 5 (a part of the fabric has been cut out from the upper left-hand side), and it will be seen that as the fabric narrows towards the bottom, the stripes become rapidly narrower and less well defined. This is a general feature of all such cases, and is due to the fact that the steady diminution in the length of yarn per course at the fashioning steadily displaces the pattern ratio from the favourable neighbourhood around 2.

The general conclusion, supported by experience is, therefore, that periods of 89 to 96 inches will often build up in stockings to give pronounced patterns. From a practical point of view they are the more dangerous periods, since a very slight defect may be greatly accentuated by the pattern formation; a shade or dyeing variation with a period of 50 to 54 inches will usually only cause complaint in a stocking when it is fairly pronounced, but a much smaller absolute colour difference may form the grounds of complaint if it occurs with the 89 to 96-inch period.

It has already been pointed out that patterns of the $b-B-b$ kind may be expected occasionally from the first group periods (50 to 54 inches) in stocking welts, but the $b-b$ pattern can also be formed from this group of hank periods at the ankle of stockings in which the fashioning has lowered the length of yarn per course to the neighbourhood of 26 inches. The same period that gives a pattern ratio near to 1 and the $b-B-b$ pattern *in the welt of a stocking*, may thus give a pattern ratio near to 2 and the $b-b$ pattern *in the ankle of the same stocking*; examples of this have been encountered in dyed stockings examined in these laboratories.

The presence of periodic shade or dyeing variations in yarn may result in the formation of patterns in hosiery knitted on circular machines, but in the experience of this Institute stockings containing such patterns and made from circular web are of much rarer occurrence than the defective full-fashioned hose with which this paper is principally concerned. The patterns built up in circular web by periodic yarn variations consist of spirals round the fabric, and one or more such spirals may be present, depending upon the length of the colour period and that of the yarn in one course. When the rate of progress of the spiral along the length of the fabric is slow, its true nature can only be detected on close examination, since the first impression produced is that of periodically recurring rings running round the fabric parallel to the courses. When the colour period is nearly equal to the length of yarn in a course, the conditions are suitable for the building-up of a pronounced

spiral pattern, but, unlike the case with flat-knitted hosiery, a period of twice this length is less favourable.

When the pattern is a simple and bold one, the period of the defect can generally be calculated from the nature and dimensions of the pattern, but when this is complicated, or its detail not clearly seen, the calculation of the period is not advisable; direct measurement from wrappings such as those described in Part 2 is in any case more satisfactory.

For hosiery knitted on a flat (full fashioned) frame, and containing the $b-b$ or $b-B-b$ pattern, the period of the colour variation is equal to

$$\frac{2CK}{CN \pm 2}$$

where C = number of courses from the centre of one dark (or light) stripe to the centre of the next immediately above or below it,

K = length of yarn in one course of knitting,

$N = 1$ for the $b-b$ pattern and 2 for the $b-B-b$ pattern. This factor is equal to the total number of *whole* diamonds in the width of the fabric.

The expression has two values corresponding to the positive and negative signs, and there is no means of deciding which is correct; the two values are not, however, very different unless the stripes are very narrow (C small).

In circular knit fabric with a spiral pattern, the period of the colour variation is equal to

$$\frac{CKT}{C \pm 1}$$

where C = number of courses between the centres of successive turns of the *same* spiral,

$T = 1$ or 2 when there is only one spiral, and 0.5 or 1.5 when there are two spirals.

The choice of sign in this expression is determined by the direction of the coloured spiral. If this is the same as the direction of knitting (the thread itself follows a general spiral path in circular web), the negative sign should be used, and the positive sign when the two directions are opposed. The alternative values of T depend upon whether the defective (light or dark) yarn occurs on every course within the spiral ($T = 0.5$ or 1) or only on alternate courses ($T = 1.5$ or 2), and this is often difficult to decide in practice unless the shade variation is large.

The calculations considered above have been simplified by restriction to the patterns most commonly encountered in hosiery.

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25—THE DECONVOLUTION OF COTTON HAIRS AS A TEST OF THE MERCERISATION PROCESS

THE "DECONVOLUTION COUNT"

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(British Cotton Industry Research Association)

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INTRODUCTION AND SUMMARY

One of the effects of immersing cotton materials in a mercerising liquor is a change in the geometrical form of the individual hairs caused by the swelling of the cellulose. Under the action of the alkali the hair loses to a greater or less extent its flat, ribbon-like, form, and acquires a more rounded or cylindrical appearance. The broad lumen of the normal unmercerised hair and the characteristic hair convolutions disappear. These changes, observed in an examination of the material under the microscope, are commonly used as the basis of a qualitative method for distinguishing between mercerised and unmercerised cotton materials. The change in geometrical form of the hairs caused by the mercerisation of a yarn or fabric can be expressed quantitatively by counting under the microscope the percentage number altered in some characteristic and definable manner by the swelling treatment, for example, from the form of a convoluted ribbon to that of an unconvoluted rod. This paper describes a counting method of this kind, and discusses its uses and limitations. The method consists in cutting a large number of hair fragments 0.2 mm. long, mounting them in liquid paraffin on a microscope slide, and counting the proportion of fragments free from twist or convolution. The result, expressed as a percentage, is called the *Deconvolution Count*. The absence of convolution is the sole criterion used to define those hair fragments included in the count, no attempt being made to distinguish those that appear "swollen" or "rounded" from those that do not. The use of short hair fragments, instead of intact hairs, facilitates good sampling and renders the measurement less exacting to the observer.

The measurement of Deconvolution Count possesses the advantages of rapidity, and of being applicable to the examination of very small samples.

Its chief practical value is for the detection of local mercerisation irregularities in material of otherwise uniform quality, particularly of irregularities due to imperfect wetting of the cotton by the mercerising liquor. It is well adapted to this purpose on account of the small sample employed, and its most important application is in the examination of mercerised hosiery yarns from this point of view.

The paper contains measurements showing the effect on the Deconvolution Count of variations in the concentration of the mercerising (sodium hydroxide) solution, and of the shrinkage permitted to the cotton during the mercerisation.

The method can be used for determining whether cotton materials have, or have not, been mercerised, and it represents a quantitative development of the simple qualitative test in which a visual estimate is formed of the freedom of hairs from convolutions by inspecting them under the microscope. In spite of the refinement of this test by expression in the quantitative form of a Deconvolution Count, occasional cases occur in which the results do not give a decisive reply to the question whether a given material has or has not been treated with a mercerising liquor. This is due to the fact that the extent to which the hairs in a cotton material deconvolute during mercerisation is not determined solely by the nature of the mercerising treatment, but is also greatly influenced by a quality of the unmercerised and unspun cotton, namely its maturity, and by the structure of the manufactured material—the twist of a yarn, or the weave of a cloth.

The dependence of the Deconvolution Count on hair, yarn and cloth structure imposes certain restrictions on the general use of the measurement for assessing the uniformity of the mercerising treatment since results obtained on materials of different structures require critical examination in the light of additional measurements before they can be interpreted. When, for example, a change of shade in dyed mercerised material is found to be accompanied by a change in Deconvolution Count, the conclusion that it is due to a variation in the mercerisation process cannot be drawn until the effects of a possible variation in raw cotton, yarn or fabric structure have been considered.

The paper also records measurements to show that if cotton is severely attacked by chemical agency prior to the mercerisation treatment, its Deconvolution Count is much lower than that obtained with chemically intact cotton, all other conditions remaining the same.

When used with due critical appreciation of the various factors that can influence it, the Deconvolution Count is a valuable *comparative* test, well adapted to examine the uniformity of a mercerising treatment. The measurement is, however, not closely related *in a general way* to the technical characteristics which constitute a successful mercerised finish. These characteristics usually consist of a particular appearance or feel, qualities not easily expressed in terms of physical quantities, and certainly not completely defined by the extent of deconvolution of the hairs. It has not been found, for example, that a mature cotton in which a large proportion of the hairs deconvolute during mercerisation yields a technically more successful result in a mercerised finish than a less mature cotton in which a large proportion of the hairs remain convoluted. Until the fundamental factors affecting the success of technical mercerisation are better understood, the Deconvolution Count possesses no *absolute* significance from a technical point of view,

and in this sense cotton materials cannot be classified as "better" or "worse" mercerised according to whether they yield high or low values for the Deconvolution Count.

It is possible to envisage other microscopic counting methods for describing the quality of mercerised cotton in which other criteria of geometrical form than the simple absence of convolutions are used as the basis of classification. The limitations noted above must however apply to a greater or less extent in all testing methods in which the observer's judgment is affected by the presence or absence of hair convolutions.

Besides the change in hair form, the process of mercerisation is accompanied by changes in other properties of cotton, and the extent of any such change can be defined arbitrarily as a measure of the mercerising effect. Some comparisons are drawn in the paper between the Deconvolution Count of mercerised cotton and its reactivity and absorptive capacity as measured by methods already described in the literature. In relation to the effects produced by the concentration of the mercerising liquor, by the shrinkage of the cotton, and by the twist of yarns, the results obtained are similar whichever method is used to measure the mercerising effect. The maturity of the unspun cotton, which has a great effect on the Deconvolution Count, is, however, without influence on the reactivity or absorptive capacity of the mercerised material.

It is very desirable that quantitative comparisons of the properties of mercerised and unmercerised cotton should be designated by purely objective names describing the operations used in the measurement, for example, Reactivity Ratio, Absorption Ratio, Deconvolution Count, etc., and not by general terms such as Degree of Mercerisation or Percentage of Mercerised Hairs. These terms are liable to misunderstanding, since they suggest standards of perfect mercerisation which vary with the method of measurement employed, and by no means completely define the practical requirements in a successful technical mercerisation process.

EXPERIMENTAL

I—METHOD

The cotton threads to be examined are cut with a special knife of which the construction is illustrated in Fig. 1. Two single edged (Vale) safety razor blades A and B are clamped tightly together by means of a brass holder made in two pieces E and F. The blades are first placed with their non-cutting edges resting on the L-shaped piece E, the piece F is fitted into position, and the whole clamped tightly together with the screws G and H. If the material to be examined is in the form of yarn, it is wrapped uniformly and compactly round a thin narrow strip of soft wood, and the resulting yarn pad is cut across at right angles to the threads by pressing the knife down on it. Very short fragments of all the cut threads are then left sticking between the two blades, their lengths being approximately equal to the distance CD between the cutting edges, or about 0.2 mm. with the blades used in the work described. The knife is then taken to pieces, the blades separated, and by means of a mounted needle the fragments of cut threads are pushed together into a little lump, which is brought into a drop of liquid paraffin on a microscope slide. The fragments are dispersed as uniformly as possible in the liquid by stirring them about with the needle

point, when the individual hair fragments easily separate from each other; a cover slip is applied, and the slide is then ready for observation under the microscope. When a periodic variation of mercerised quality is suspected in a hank mercerised yarn, it is usually necessary to compare relatively short lengths of thread, for example, lengths that have dyed different shades. If a match stick of square section is used as the wrapping core the technique demands no more than a few inches of yarn, every hair in that length being sampled in the cutting.

If the material to be examined is in the form of fabric, a few warp (or weft) threads are removed over a short distance, and the exposed band of weft (or warp) is cut on a soft wood base exactly as with the yarn pad.

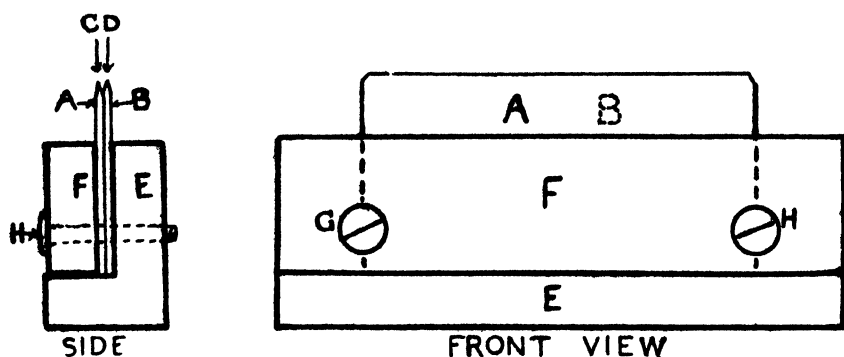


FIG. 1

Knife used in the preparation of hair fragments for the determination of Deconvolution Count

The slide is systematically traversed under the microscope, a magnification of about 200 being convenient, and a count is made (a) of the total number of fragments viewed, and (b) of the number judged to be free from convolutions, twists, and folds. It is necessary to focus separately on individual fragments, and no fragment is included in group (b) that contains either a number of complete convolutions through 360° , or a partial twist about the hair axis through a smaller angle. The ratio of (b) to (a), expressed as a percentage, is called the Deconvolution Count, and in order to obtain the mean values recorded in this paper the total number of fragments counted was from 700 to 1,000 in each separate determination of the count. Fig. 2 is a camera lucida drawing of a typical field (a) of fragments from a hosiery yarn before mercerisation, and (b) of fragments from the same yarn mercerised in hank form; the field (a) contains only one fragment that would be included in a count, whilst in field (b) all the fragments except three would be counted.

The counting is greatly facilitated by the use of two small automatic counters mounted side by side on a heavy metal base. The slide is traversed by the operation of the mechanical stage with the observer's right hand, whilst the left hand is used to operate the counters, all the observed fragments being recorded on one counter with one finger, and only the deconvoluted fragments on the second counter with another finger of the same hand. With this arrangement it is possible to count large numbers of fragments continuously without fatigue; after a little practice, the observer can prepare a slide and count 1,000 fragments in half an hour. A cut made across a band of threads the full width of the knife blades ($1\frac{1}{4}$ inches) provides tens

of thousands of fragments, and the slide is too dense for convenient counting if the whole of this is used, fields of view containing five to ten fragments being the most suitable.

The method described above, in which hair fragments are used, was adopted after preliminary trials of other possible methods, and the technique is less exacting than one in which intact hairs are observed. Since the fragments, unlike intact hairs, do not cling together, they can easily be dispersed in a liquid medium, and much less effort is required in counting many fields each containing only five to ten short fragments than in counting few fields each containing many more or less intertwined and superimposed hairs; in addition, the labour of forming an approximately single layer of parallelised hairs on the microscope slide is avoided.

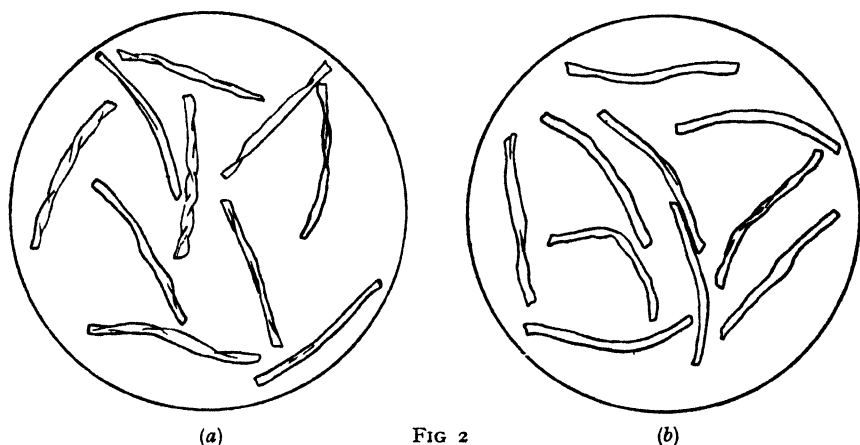


FIG 2
Camera lucida drawings of fragments from a hosiery yarn (a) before mercerisation; (b) the same yarn after mercerisation in hank form.

II—SAMPLING AND THE REPRODUCIBILITY OF RESULTS

Great advantages of the method are the ease of sampling, and its adaptability in this respect to the examination of materials ranging from an inch of yarn to a hundred yards or more of cloth.

The examination of short lengths of yarn can be illustrated by the technique used in an experiment described later in para. IIIc (ii), designed to test the relation between variations of twist and variations of Deconvolution Count occurring within the same mercerised yarn. In this experiment a long length of yarn had been examined under the microscope, and by means of ink spots made on the yarn, six specimens only $\frac{1}{8}$ inch long had been marked out at different places on the continuous thread where the twist was abnormally high; six other specimens $\frac{1}{8}$ inch long had been similarly marked where the twist was abnormally low. In order to determine the Deconvolution Count in the places of abnormally high twist, for example, lengths of about 6 inches of yarn were cut out containing the six marked $\frac{1}{8}$ -inch specimens in the middle of the pieces, and these lengths were laid across a strip of damped adhesive tape made from transparent paper as used for repairing torn manuscript. The six pieces of yarn were so arranged that they lay compactly side by side with the marked $\frac{1}{8}$ -inch lengths exactly opposite one another in the middle of the tape. A second piece of damp tape was pressed down on top of this, forming a sandwich in which the six specimens

were rigidly held by the adhesive backing on both sides. The unwanted ends of yarn and of paper strip were then cut off leaving a rigid specimen a little wider than the width of six threads laid side by side. This could be cut across many times with the knife, a different place on the blades being used for each cut, and the combined fragments from all the cuts brought on to the microscope slide. The fragments easily became detached from the very thin strips of paper backing when they were stirred with a needle in the drop of paraffin, and the six $\frac{1}{8}$ -inch yarn lengths were very effectively sampled in this way.

The use of a paper backing for short yarn lengths as described above is very convenient in the examination of periodic shade variations in dyed mercerised yarns for the purpose of determining whether these are associated with variations in the hank mercerisation process. A considerable length of the dyed yarn is wrapped compactly on a steel rod of about 2 inches circumference, and the whole yarn surface is covered with the damped adhesive tape applied in one or more strips parallel to the axis of the rod. The yarn is then cut away from the rod with a single razor incision parallel to its axis, and a flat yarn pad is then obtained held together by the transparent paper backing. Periodic shade variations in the yarn form alternating darker and lighter bands in such a pad, each band consisting of 2-inch lengths of yarn laid side by side. These bands with their paper backing can be cut out with scissors, and a number of, for example, light bands laid side by side and sampled as a whole with one knife cut, or different individual light bands can be individually sampled along their lengths, with several knife cuts, for comparison with the dark bands similarly treated. The efficiency of sampling by this method is practically perfect.

In the examples given above, the problems were concerned with possible local irregularities in Deconvolution Count correlated with visible irregularities in twist or colour. If a representative figure is required for a large sample of material, several cuts the full width of the blades can be made at a number of random places, and the resulting fragments well mixed by stirring in a small volume of liquid paraffin; only a fraction of this, containing a sufficient number of fragments to yield a slide of reasonable density, is used for the observation.

In order to illustrate the sampling of long lengths of cloth, figures are quoted below for the Deconvolution Count of the warp in three mercerised two-fold poplins numbered 1, 3, and 5. These were technically mercerised in 200-yard lengths, and it was desired to compare the results. From each 200-yard length, two one-yard samples were taken, one 50 yards from the beginning, and the other 50 yards from the end, of each complete length. In each 1-yard sample three cuts were made across the warp threads the full width of the knife blades, one from the top right-hand side, one from the middle centre, and one from the bottom left-hand side. The fragments from the three cuts were well mixed in a drop of paraffin, the number of hairs each represented by a single fragment in this drop being of the order of 100,000. A fraction of the paraffin containing a suitable number of fragments to give a slide of reasonable density was removed, and a Deconvolution Count made. The separate results on the two 1-yard samples removed by 100 yards from one another in each of the three complete lengths of cloth are given below—

		Sample No.	1	3	5
Deconvolution Count	1st Slide ...	...	57	25	45
	2nd Slide ...	...	53	25	49

The efficiency of sampling by the methods described is so good, and the rapid counting of a large number of fragments so simple, that the uncertainty in the result due to the inherent variability of cotton materials can easily be reduced to a very low figure. The reproducibility of results is determined almost entirely by the certainty with which a fixed standard of judgment can be maintained in the classification of the fragments; that is, by so-called "observer errors" depending upon differences in judgment of different observers, or of the same observer at different times. Such errors are important in all microscope counting methods involving a judgment of the geometrical form of the hair, and the presence or absence of convolutions was chosen as the sole basis of the observations in this paper in the expectation that the simplicity of the criterion would assist in the maintenance of a rigid standard of judgment. From this point of view the reliability of a result can only be estimated by actual experience with the method. It is found that the same trained observer counting the same slide on the same day generally obtains results which do not differ by more than five in the percentage, though duplicate counts made at much longer intervals by the same observer may differ by somewhat more than this. Two observers trained in the same laboratory counting the same 11 slides obtained the following differences in percentage counts that varied continuously from 20 to 80—+3, ± 0 , +2, +1, +2, -4, ± 0 , -3, ± 0 , +5, +3. Greater differences might of course be expected between two observers trained in different laboratories without the opportunity of a direct comparison and adjustment of standard in the actual course of work.

III—THE DECONVOLUTION COUNT OF MERCERISED COTTON

(a) The Effect of Concentration of Sodium Hydroxide

Two soft-twisted hosiery yarns (2/50) were mercerised by thorough wetting out with hot water and subsequent immersion without tension for 30 minutes in sodium hydroxide solutions of concentration ranging from 2*N.* to 10*N.* at the temperature of the laboratory. They were washed, dried, and their Deconvolution Counts were determined with the following results, which are plotted in Fig. 3.

Table I

Concentration of NaOH ...	...	...	0	2 <i>N.</i>	3 <i>N.</i>	4 <i>N.</i>	5 <i>N.</i>	6 <i>N.</i>	8 <i>N.</i>	10 <i>N.</i>
Deconvolution Counts—										
Sample 150, Tangus	...	...	13	14	23	65	68	72	79	85
Sample 152, Brazil	...	...	9	9	12	42	47	50	61	67

As the concentration of the alkali is continuously increased the Deconvolution Count is not greatly affected until the concentration reaches about 3*N.* (24° Tw.). Between 3*N.* and 4*N.* (24° Tw. and 31° Tw.) it rises extremely rapidly, and thereafter only slowly, so that in the range of normal technical mercerising liquors, 50° to 60° Tw. (7*N.* to 8.7*N.*), the Deconvolution Count is insensitive to small variations in the concentration of the liquor.

(b) The Effect of Variety of Cotton

Although the two yarns examined in the last paragraph were treated identically in the mercerisation process they yielded different values for the Deconvolution Count over the whole concentration range. Eleven different

varieties of cotton in the form of soft-twisted hosiery yarns (long staple 2/50, 14 turns per inch; short staple 2/24, 19.20 turns per inch) were well wetted out and immersed together for 30 minutes in 7.5*N.* sodium hydroxide at the temperature of the laboratory. The samples were washed and dried and their Deconvolution Counts determined with results given in Table II.

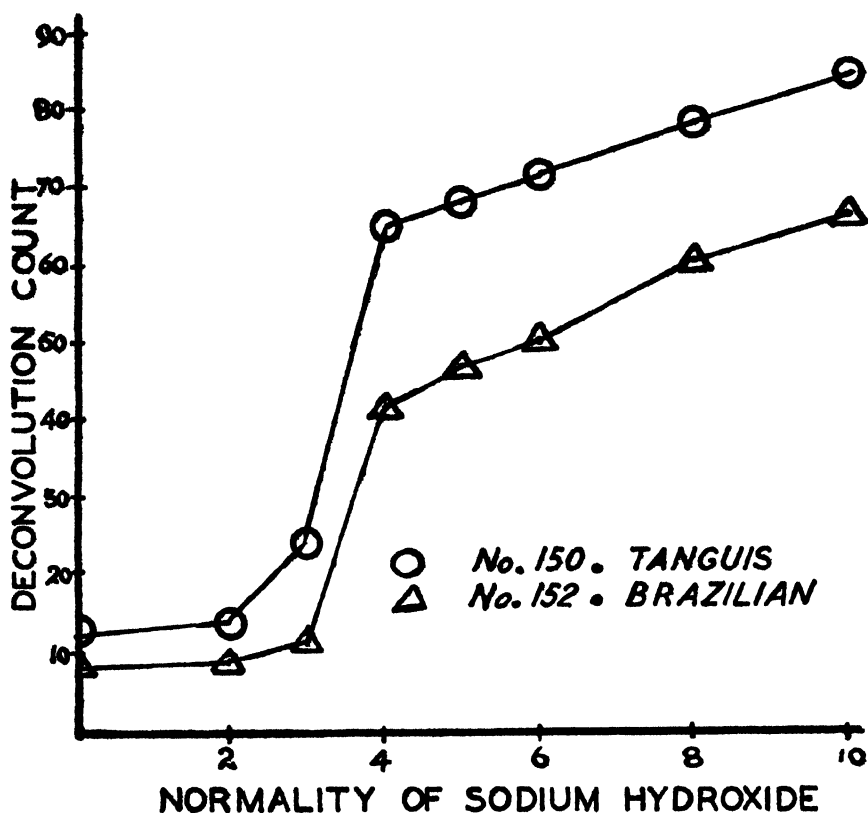


FIG 3

Relation between concentration of mercerising liquor and Deconvolution Count.

The table shows that yarns of similar construction but spun from different varieties of cotton exhibit a very wide range of Deconvolution Counts after identical mercerisation treatment. The particular quality of the cotton hair responsible for this wide variation is the thickness of the hair wall in relation to the total width of the hair, and may be described as the maturity of the cotton. A method of testing, called the Immaturity Count, has been described by Clegg⁴ in which the hairs in a sample of cotton are classified as normally mature, thin walled, and dead, this classification depending upon the geometrical form of the hair whilst immersed in a sodium hydroxide solution. The above table includes the results of Immaturity Counts made by Clegg's method on some of the samples, and there is evidently a relation between the two measurements, the Deconvolution Count falling as the percentage of normally mature hairs diminishes.

Table II

Sample	Deconvolution Count	Immaturity Count		
		% Normal	% Thin Walled	% Dead
No. 133 Egyptian Uppers (2/50)...	79			
No. 156 Peruvian Tanguis (2/50) ...	65	82	14	4
No. 153 " Mitafifi (2/50) ...	58			
No. 239 " Iquitos (2/24) ...	58	64	24	12
No. 241 Indian Dharwar (2/24) ...	51			
No. 230 American Texas (2/24) ...	49	70	23	7
No. 244 " Memphis (2/24) ...	47			
No. 231 " " " " (2/24) ...	31			
No. 236 Australian Durango (2/24) ...	28			
No. 234 African Zaria (American Seed) (2/24) ...	28	42	38	20
No. 151 American Arizona Pima (2/50)...	20	33	47	20

(c) The Effect of the Structure of Manufactured Goods

(i) A Comparison of Yarns with Unspun Cotton.

Soft-twisted two-fold hosiery yarns (Nos. 133, 230, 234 in Table II) made from three different cottons, bundles of intact hairs of the same cottons, and 0.2 mm. fragments cut from the yarns, were all immersed in 7*N.* sodium hydroxide solution, washed with water and dried. Fragments were then cut from the yarns and from the hair bundles, and these, together with the fragments mercerised as such, were separately mounted in paraffin, and Deconvolution Counts made with the following results—

Table III

Cotton Sample		Deconvolution Counts after Mercerisation		
		As Yarn	As Intact Hairs	As Hair Fragments
No. 133	Uppers ...	79	82	81
No. 230	Texas ...	45	71	79
No. 234	Zaria ...	28	56	68

In these experiments the only variable was the form of the material during mercerisation, and this is seen to exert an influence on the Deconvolution Count that varies with the variety of cotton. The Uppers sample, which yielded a high value for the count, gave substantially the same result irrespective of its form during mercerisation. The Zaria sample, which gave a very low value when mercerised in yarn form, showed a much higher Deconvolution Count when mercerised as hairs, and a still higher result when mercerised in the form of hair fragments. The behaviour of the Texas sample was intermediate between the other two; it yielded a much greater count after mercerising as hairs than as yarn, but the result obtained with the hair fragments was only slightly higher than that given by intact hairs.

The results recorded above can be explained in the following way—When cotton materials are immersed in a mercerising liquor forces are set up in the individual hairs tending to cause them to deconvolute. The extent of the

deconvolution is more or less affected by the external resistance to deconvolution. This is greater in yarn than in unspun hairs, and greater in intact hairs than in hair fragments. The tendency to deconvolute is greatest in the most mature cottons, and in the first sample in the above table (Uppers) it is sufficiently great to obscure any effect on the Deconvolution Count of a variation in structure from a soft-twisted yarn to hair fragments. In the immature sample (Zaria) there is much less tendency to hair deconvolution, and the extent of deconvolution is then greatly affected by the structural variations.

(ii) *A Comparison of Yarns spun with different Twists from the same Cotton.*

It might be anticipated that the Deconvolution Count obtained for a given cotton in a given mercerisation process would depend, not only upon whether the fibre was spun or unspun, but also upon the precise structure of the yarn. A more compact structure would offer a greater resistance to hair deconvolution, and would result in a lower count. Results are given below for nine two-fold yarns doubled from the same single 40's carded Sakel (19 turns per inch warp way) with different two-fold twists. The yarns were immersed for five minutes on a hank mercerising machine in 7.5*N.* sodium hydroxide containing a wetting agent (*a*) at a constant length, that is, permitting no shrinkage either during impregnation or washing, and (*b*) allowing the yarns to shrink until they just became slack on the rollers and washing in the shrunk state. The samples were dried, and their Deconvolution Counts determined.

Table IV

Sample No....	1	2	3	4	5	6	7	8	9
Direction of Doubling	Weft Way					Warp Way			
Doubling Twist, turns per inch	13½	18	22½	27	36	9	18	27	36
Deconvolution Counts—									
No Shrinkage	45	45	38	31	26	37	17	14	9
Shrinkage	50	56	52	48	40	54	42	20	15

The two series of yarns (doubled weft and warp way) will be considered separately. In the weft-way series when the cotton was allowed to shrink during mercerisation, an increase of twist from 13½ to 27 turns per inch was without any very significant effect upon the Deconvolution Count, but a further increase in twist to 36 turns per inch resulted in an appreciable fall. When the shrinkage of the cotton during mercerisation was prevented the effect of increasing twist was slightly emphasised, the fall in Deconvolution Count becoming appreciable at a twist of 27 turns per inch. In the warp-way series a continuous effect of increasing twist was observed throughout the range examined, in the expected direction of lower Deconvolution Counts with increasing compactness of yarn structure; this was true both when shrinkage was permitted and when it was prevented during mercerisation.

In a comparison of the two series of yarns (doubled warp and weft way), it must be remembered that the single ends were spun warp way, and therefore that the two-fold yarns with weft-way doubling twist represent much less compact structures than the corresponding two-folds doubled warp way. When this is borne in mind, the comparison of the results obtained with the two series is in qualitative agreement with the rest of the data.

For the practical appreciation of the results it should be noted that the first two yarns in the table are soft, and more or less comparable in structure

with hosiery yarns, but a number of the others, particularly those doubled warp way, are extremely hard, and can only be compared with crêpe yarn. The differences of twist used to display the effect of this factor on Deconvolution Count are much greater than could occur in nominally the same "yarn quality" as this term is understood in the trade.

With the hard-twisted samples it is possible that five minutes' treatment on the mercerising machine was insufficient to secure complete penetration of the material, and that the low values of the Deconvolution Count are to some extent due to the fact that the core of the yarn was never in contact with the alkali. This point will be considered again in paragraph Va.

A second series of results, to be given below, illustrates the effect of twist on the Deconvolution Count of *single* yarns, all spun from the same cotton to 26's count, and mercerised together under tension on the rollers of a hank mercerising machine as in normal trade practice, the maximum stretch corresponding to a hank circumference of $52\frac{1}{2}$ inches.

Table V

Average Twist, turns per inch	...	...	...	12.1	20.7	23.0	35.7	38.9	46
Deconvolution Count	...	...	...	69	58	53	41	35	30

This table also shows the effect of increasing twist, or increasing yarn compactness, in restraining the deconvolution of hairs.

On account of the variability of cotton materials differences of twist exist between *short lengths* of the *same yarn* comparable with, or greater than, the differences between the average twists for two successive samples in the above yarn series; a corresponding variation in Deconvolution Count might therefore be expected between *short lengths* of the same mercerised yarn.

For one of the yarns in the above series, the twist was observed by a microscope method in many specimens $\frac{1}{2}$ inch long over a considerable yarn length, and some of the specimens were divided into three groups—(a) those of near the average twist, namely, from 17 to 20 turns per inch, (b) abnormally high twisted specimens with above 26 turns per inch and (c) abnormally low twisted specimens with turns below 13 per inch. (The average twist in specimens a few inches in length would of course show a much smaller variability.) Deconvolution Counts were made separately on the three groups of specimens with the following results, which confirm the suggestion that variations of twist within a mercerised yarn are associated with variations in Deconvolution Count.

Abnormally high twist	...	...	...	46
Average twist	...	...	...	52
Abnormally low twist	...	...	...	58

(iii) *The Woven Structure.*

From the results already given it will be clear that the Deconvolution Count of a mercerised fabric must be affected by a number of factors besides the precise conditions of mercerisation. The warp and weft threads are generally spun from different raw mixings that may differ considerably in maturity, and this factor alone may cause large differences between the Deconvolution Counts of the two sets of threads. The twist of warp and weft yarns will also be different in most cases, and this is a second factor affecting the results. In addition, however, the interlacing of two sets

of threads at right angles in tightly woven structures presents a great resistance to the deconvolution of individual hairs, and as a matter of experience, it can be said that the Deconvolution Counts observed on technically mercerised cloths range round a much lower mean than that obtained with technically mercerised yarns. The constraint imposed by the woven structure may be very different in the warp and weft directions, and this is the third factor affecting the comparison of Deconvolution Counts for warp and weft yarns. Thus in a poplin cloth there are about twice as many warp threads per inch as weft, and consequently a given length of any weft thread is crossed twice as often by warp threads as any warp thread is crossed by weft in the same length. Although the effect is occasionally obscured by other variables (maturity, yarn twist), a comparison of the Deconvolution Counts in the warp and weft threads of mercerised fabrics generally shows a higher value for the preponderating set of threads, a result to be expected from the above considerations. The statements made above are illustrated by the following experiments.

A sample of a poplin cloth woven from single yarns was scoured, wetted out in hot water, immersed in 7*N.* sodium hydroxide solution for five minutes without restriction on its shrinkage, well mangled in the liquor, and replaced in it for 30 minutes. At the same time some of the warp yarn removed from the cloth was submitted to the same treatment, whilst a further sample of warp yarn from the cloth was wrapped on a frame to prevent shrinkage, and immersed for the same length of time in the same mercerising liquor. The Deconvolution Counts of the warp yarn mercerised under these various conditions, washed and dried, were as follows—

Warp mercerised as a part of the cloth with no external restraint on shrinkage	...	...	...	...	...	...	...	20
Warp yarn mercerised separately, but wrapped on a frame to prevent shrinkage	...	...	...	...	...	...	...	46
Warp yarn mercerised separately with no external restraint on shrinkage	...	...	...	...	...	...	...	60

In view of the thorough impregnation of the materials with the mercerising liquor, the different results obtained by mercerising the thread in the cloth and as unwoven yarn can only be ascribed to the resistance offered by the cloth structure to the deconvolution of the hairs.

For three finished poplins made from the same grey cloth but technically mercerised in three different works, the Deconvolution Counts on warp and weft were—

		Sample No.			1	3	5
Deconvolution Count	Warp	...	...	...	55	25	47
	Weft	...	...	...	31	15	21

The differences between the three values for the warp threads or those between the three values for the weft threads, reflect differences between three mercerisation processes, but the difference between values for the warp and weft threads in one sample is for the most part merely a reflection of the cloth structure. In order to show this, individual threads were removed from the corresponding unmercerised cloth and were mercerised in the laboratory by immersion for five minutes in 7*N.* sodium hydroxide solution. Their Deconvolution Counts were then 79 on the warp and 64 on the weft—relatively a much smaller difference between the two sets of threads than in the technically mercerised materials. Since the warp (2/100's) was

doubled weft-way from a warp-way single yarn, whilst the weft (2/80's) was doubled warp-way from a warp-way single yarn, the difference in Deconvolution Count after laboratory mercerisation in yarn form is in the direction of a lower value for the more compact yarn. Whether the difference between the values obtained for warp and weft in the materials is completely accounted for by these differences imposed by cloth and yarn structures, or whether a difference in the raw cotton quality also contributes, can be determined by untwisting warp and weft threads, mercerising the cottons in the form of unspun hairs, and again determining Deconvolution Counts. The results were 81 for hairs removed from the warp threads and 82 for hairs from the weft. The value given by the warp does not differ significantly from that obtained when it was mercerised in yarn form (79), but that given by the weft is considerably higher than the value obtained for mercerised weft yarn (64). The complete evidence leads to the conclusion that the difference in Deconvolution Count between the warp and weft of these particular mercerised poplins can be entirely accounted for by the structural difference in warp and weft directions.

A problem which has been discussed in the technical literature is that of determining whether the mercerising liquor penetrates effectively into the structure of a cloth, wetting not only its surface, but also the less accessible parts of the material. The evidence already given renders it improbable that the solution of this problem can ever be obtained by microscopic examination of hair form, since the less accessible parts of the cloth are necessarily those in which the individual hairs are subjected to more constraint. Even for ideal penetration the hairs buried deep in the cloth structure must be expected to show a smaller *mercerised effect* as judged by the absence of convolutions, than the hairs nearer the surface, since the resistance to deconvolution is greater in the interior of the fabric. It is possible to show experimentally that even after prolonged treatment with a mercerising liquor, the hairs, or portions of hairs, lying near the surface of a mercerised fabric may be more completely deconvoluted than those embedded in the cloth.

In order to obtain such evidence it is only necessary to be able to distinguish in a slide, prepared for the Deconvolution Count, between hair fragments originally on the surface of the fabric and those from its interior. This can be done in the following way—The cloth is dyed a heavy shade with the yellow dye Primuline (15% on the cloth weight, with the addition of salt to the bath). The dye is diazotised on the fibre, and the dyeing then exposed for a few minutes to sunlight. This results in the decomposition of the diazotised colour, and when the dyeing is subsequently developed in the ordinary way with β -naphthol, to produce the familiar deep red colour of the developed Primuline, the surface that has been exposed to light fails to develop; it remains yellow, whilst the interior of the material, which was shielded from the light, is deep red. A few trials with different times of exposure to the light enable the depth of the yellow surface layer to be adjusted to a larger or smaller fraction of the total thickness of the fabric. Fragments cut from such a material can then be divided into two groups (a) those that are completely yellow, or yellow over some proportion of their length, and (b) those that are completely red, the second group consisting of portions of hairs more deeply embedded in the cloth structure than those in the first group. For the warp of a scoured cloth mercerised without

tension by 30 minutes' treatment in the laboratory with 7*N.* sodium hydroxide solution, and investigated by the above technique, the following results were obtained—The totally or partially yellow fragments formed 25% of the whole, and yielded a Deconvolution Count of 56, whilst the totally red fragments (the remaining 75%) yielded a value of only 35. This difference in the count represents the effect of isolating one "surface" (25% of the thickness) from the remainder of the cloth, and a greater difference would have resulted if, by light exposure on both sides, both "surfaces" had been isolated.

(d) **The Effect of Shrinkage during Mercerisation**

Table IV (p. 1242) contains data enabling a comparison of Deconvolution Counts to be made for two-fold cotton yarns with a range of twists (*a*) when yarn shrinkage was completely prevented, and (*b*) when the yarn was allowed to shrink to its maximum extent. The result of preventing shrinkage was in all cases to produce a lower Deconvolution Count in the tensioned than in the shrunk material. This effect is, however, relatively much greater in the more tightly twisted than in the softer yarns. Differences in shrinkage considerably less than the maximum, but sufficient to produce large differences of lustre and dyeing shade, have a barely significant effect on the Deconvolution Count of soft-twisted hosiery yarns. Thus, three 2/40's hosiery yarns were mercerised for five minutes in 7.5*N.* sodium hydroxide on the hank machine (*a*) without permitting any shrinkage, and (*b*) allowing the 54-inch hanks to shrink to 50 inches (complete shrinkage would correspond to about 45-inch hanks). Their Deconvolution Counts were as follows—

Sample No.	No Shrinkage				With Shrinkage			
1. Sakel	63	...	...	...	68
2. Brazilian	41	...	...	...	42
3. Arizona Pima	15	...	...	...	22

(e) **The Effect of Temperature of Washing, and of Repeated Mercerisation**

The effect of the temperature of the wash water upon the Deconvolution Count of mercerised cotton is illustrated by the measurements given below. Two hosiery yarns of similar structure, one spun from a Sakel cotton of average maturity and the other from a very immature Arizona cotton, were mercerised by immersion in 7.5*N.* sodium hydroxide (*a*) allowing complete shrinkage, (*b*) preventing shrinkage. One sample of each cotton was washed in a large bulk of water at the ordinary laboratory temperature, and another sample of each in a large volume of boiling water; the yarns were then dried at room temperature and their Deconvolution Counts determined with the following results—

		Mercerised with Shrinkage		Mercerised without Shrinkage	
		Washed Cold	Washed Hot	Washed Cold	Washed Hot
Sakel Cotton	...	82	74	55	65
Arizona Cotton	...	31	24	20	18

The effect of the temperature of washing is small, and differs according to whether the yarn is, or is not, allowed to shrink. When shrinkage is permitted, washing in cold water produces a higher Deconvolution Count than washing in hot with both cottons, but when shrinkage is prevented the higher value is given by the hot washing in the case of the Sakel cotton, whilst with the Arizona yarn the temperature of washing is without significant effect. It is possible to explain these results on the assumption that a greater swelling occurs during the washing process at the lower temperature. This

would account for the greater deconvolution of the hairs submitted to no external restraint. When, however, shrinkage is prevented, the greater swelling during cold washing would result in the development of a higher tension in the yarn, and this effect by itself would restrain the deconvolution of the hairs. Under these conditions, therefore, the greater deconvolution tendency caused by the greater swelling, might be more or less counter-balanced by the greater resistance to deconvolution imposed by the same cause; the net effect of the temperature of washing on the Deconvolution Count could not then be predicted.

Repeated mercerisation (immersion in sodium hydroxide solution followed by washing with water) results in an increase in the Deconvolution Count. The yarn of Arizona cotton referred to above was treated ten times alternately with 7.5*N.* sodium hydroxide solution and cold water, and its Deconvolution Count rose from 31 after one treatment to 52 after ten treatments. Unspun hairs of the same cotton treated in the same way gave Deconvolution Counts rising from 47 after a single treatment to 70 after ten treatments. It should be noted that this rise in Deconvolution Count cannot be obtained simply by increasing the time of treatment of the cotton with the sodium hydroxide solution in a *single* mercerisation (immersion and washing) process. Substantially the same values were obtained, for example, whether the time of immersion of these hosiery yarns was 5 or 30 minutes in the single treatment.

(f) The Effect of Chemical Attack of the Cellulose prior to Mercerising

A scoured yarn was treated for various times with hydrochloric acid of concentration 200 grams per litre at 20° C. in such a way as to produce a series of samples in which the cellulose had been degraded by acid attack to increasing extents. These samples were mercerised by immersion without tension in 7*N.* sodium hydroxide solution for five minutes, washed and dried. The following table records the Deconvolution Counts of the mercerised samples, and, as a measure of the extent of previous chemical attack, their fluidities (reciprocal poises) in 0.5% cuprammonium solution, Sample No. 1 being the yarn without any acid treatment.

Table VI

Sample No.	...	...	...	...	1	2	3	4	5	6
Fluidity	...	...	...	...	3.6	18.5	22.6	32.0	36.0	39.2
Deconvolution Count	...	...	...	...	69	70	58	37	32	23

The initial stages of the chemical attack are without much effect on the Deconvolution Count of the material subsequently mercerised, but more severe attack is accompanied by a great reduction in the value. It has already been observed by Bright² that cotton hairs attacked by sulphuric acid and subsequently immersed in a sodium hydroxide solution of mercerising concentration are "not fully swollen to the rod shape, but remain corrugated."

IV—THE DECONVOLUTION COUNT OF UNMERCERISED COTTON AND THE USE OF THE METHOD FOR CHARACTERISING MERCERISED MATERIALS

The Deconvolution Count of unmercerised cotton is never zero, that is, among hair fragments 0.2 mm. long, cut from any unmercerised cotton, a certain percentage is free from convolutions. Table VII records the values obtained on a fairly wide range of cotton varieties in the *unmercerised* state.

Table VII

Number	Sample	Deconvolution Count
106	Indian, Bengal	16
239	Peruvian, Iquitos	14
241	Indian, Dharwar	14
159	Sea Island	13
150	Peruvian, Tanguis	13
130	Egyptian, Sakel	12
128	Egyptian, Uppers	12
152	Brazilian, Long stapled	9
230	American, Texas	9
151	American, Arizona Pima	4
234	African, Zaria (American seed)	2.5

The object of these data is merely to show what range of values may be expected from unmercerised materials, and not to study the significance of the measurement applied to raw cottons. It may, nevertheless, be of assistance to indicate some of the factors that determine the Deconvolution Counts of unmercerised cottons. When the cotton boll bursts, the hairs dry up, their walls collapse, and the spiral structure of the walls causes the hairs to twist into the form of convoluted flattened tubes. If, however, the walls are abnormally thick in relation to the total width of the hair, they cannot collapse, and the hairs do not then convolute. If, on the other hand, the walls are abnormally thin, the hairs collapse, but the thin walls exert relatively slight twisting influence, and the hairs again remain unconvoluted. Thus the number of convolutions per unit length of the hair depends upon the degree of thickening of the wall, being relatively small for *both* abnormally thick, and abnormally thin, walled hairs. All cotton varieties contain certain proportions of abnormally thick, of abnormally thin (immature or dead), and of normally developed hairs, and the distribution in these classes describes what is called the maturity of the sample (Clegg, *loc. cit.*).

The Deconvolution Count does not distinguish between hairs free from convolutions because abnormally thick, and those free from convolutions because abnormally thin. It is to be anticipated in a general way that immature growths containing a relatively high proportion of very thin walled hairs will contain a relatively low proportion of very thick walled hairs; the presence of the former tends to increase, the absence of the latter to decrease, the Deconvolution Count. It is not, therefore, possible to predict without experimental evidence what effect the maturity of the sample will exert on its Deconvolution Count. The two lowest values in Table VII are given by cottons shown in Table II to be very immature, and it follows from this that the presence of a relatively high proportion of unconvoluted thin walled hairs in these growths is *more than compensated for* by the absence of the normal proportion of unconvoluted thick walled hairs.

The above results are of importance in the use of the method as a means to distinguish between mercerised and unmercerised cotton materials. If a value exceeding 20 is obtained for the Deconvolution Count, it can be concluded that the material has received a mercerising or similar swelling treatment, whilst if the value is below 10 the conclusion is justified that the material is unmercerised. Values between 10 and 20 unsupported by other evidence are ambiguous in their interpretation since compact yarn and fabric structures, particularly if made from immature cottons, may yield no higher values after a technical mercerising treatment.

V—COMPARISON OF DECONVOLUTION COUNTS WITH OTHER MEASURES OF MERCERISED QUALITY

(a) Laboratory Measurements of Reactivity and Absorption

The effect of the concentration of the mercerising alkali upon the mercerised quality of the cotton is the same, whether this quality is measured by Deconvolution Count, by the chemical reactivity of the material, or by its absorptive capacity. This is shown by the fact that when the reactivity in hypobromite oxidation, the absorption of alkali from dilute solution, or of water vapour from an atmosphere of constant humidity, is plotted against the concentration of mercerising sodium hydroxide, the curves obtained all resemble closely in shape that of Fig. 3, in which the Deconvolution Count is similarly plotted.^{1,3,6} This is the typical "Mercerisation Curve."

The effects of variable twist on the properties of yarns mercerised under constant conditions, and of the restriction of shrinkage during mercerising, are also qualitatively similar whichever measurement is used to describe the quality of mercerisation. This is shown in Table VIII by measurements of alkali absorption ratio (copper from dilute cuprammonium hydroxide solution),³ and of reactivity ratio (in hypobromite oxidation),¹ made on the series of mercerised yarns already described in section IIIc (ii); the series 1 to 5 represents increasing twofold twist in a direction opposite to that of the single yarn, and the series 6 to 9 increasing twofold twist in the same direction as that of the single yarn.

Table VIII

Sample No	Deconvolution Count		Alkali Absorption Ratio		Reactivity Ratio	
	No Shrinkage	With Shrinkage	No Shrinkage	With Shrinkage	No Shrinkage	With Shrinkage
1	45	50	1.67	1.91	1.47	1.47
2	45	56	1.63	—	1.42	—
3	38	52	1.58	—	1.47	—
4	31	48	1.62 (?)	—	1.30	—
5	26	40	—	1.76	—	1.39
6	37	54	1.61	—	1.37	—
7	17	42	1.25	—	1.28	—
8	14	20	1.24	1.66	1.17	1.37
9	9	15	1.26	—	1.12	—
Unmercd. Cotton	11	—	1.00	—	1.00	—

An examination of these results shows that the three measurements are affected in the same direction by increasing yarn compactness and by the application of tension during mercerising (prevention of shrinkage). In a quantitative sense the effect of these factors varies considerably according to the nature of the measurement. The two most highly twisted samples 8 and 9, mercerised without shrinkage, do not, for example, differ significantly from the unmercerised cotton in Deconvolution Count, but are very significantly higher in Alkali Absorption and Reactivity Ratios. There are also large differences in the effect of tension on the different properties; thus sample 8 allowed to shrink during mercerising yields as high an Absorption Ratio as Sample 1 mercerised without shrinkage, whilst the Deconvolution Count varies from 20 to 45. If the effects produced by tension and

yarn structure were due solely to the influence of such factors on the penetration of the yarn by the mercerising liquor these results would be anomalous, and they are evidently controlled largely by the specific effect on each measurement of the structural resistance to hair swelling and deconvolution.

The variety of the raw cotton, which has been seen to exert a great influence on the Deconvolution Count of the mercerised manufactured material, has little effect upon reactivity and absorptive capacity. This constitutes a very important difference between the methods of describing mercerised quality based on observations of hair deconvolution, and those based on chemical or physico-chemical measurements. Table IX contains the results yielded by six two-fold hosiery yarns spun and doubled in the same way from different cottons, and mercerised together on a hank mercerising machine according to customary trade practice.

Table IX

Cotton		Deconvolution Count	Reactivity Ratio	Alkali Absorption Ratio	
				Sodium Hydroxide	Barium Hydroxide
150	Tanguis ...	73	1.43	1.64	1.66
133	Uppers ...	66	1.46	1.57	1.61
153	Peruvian Mitafifi ..	65	1.45	1.68	1.66
132	Sakel ...	63	1.38	1.57	1.57
152	Brazilian ...	51	1.42	1.62	1.70
151	Arizona Pima ...	23	1.34	1.62	1.70

The Arizona Pima, and to a lesser extent the Brazilian, sample were thin walled, immature cottons. They gave correspondingly low values for the Deconvolution Count, but these differences are not reflected in the values obtained for reactivity and absorption ratios.

(b) The Technically Important Qualities of Mercerised Cotton

From a technical aspect, the most coveted quality of mercerised materials usually consists in some more or less characteristic appearance or feel, though occasionally cotton is mercerised purely for the purpose of securing a maximum absorption of dyestuffs by the material. Of these desirable qualities, probably the most important is a high lustre. There is no general relation between the lustre and the Deconvolution Count of mercerised cotton, though under a given set of conditions they may be closely correlated on account of both being affected in the same sense by a variation of a particular kind. Thus for yarns mercerised under tension, lustre and Deconvolution Count are similarly affected by variations in the twist of the yarn, and this is illustrated by the series of samples for which measurements have already been given in Table V. With these single yarns spun to the same counts from the same cotton with different twist factors, the lustre of the mercerised material steadily diminished as the Deconvolution Count fell, that is, with increasing yarn twist.

Other factors of importance in determining the Deconvolution Count either have little influence on lustre, or affect it in an opposite sense. This is most evident in the effects of the extent of yarn or cloth shrinkage permitted during the mercerisation process, where the maximum shrinkage corresponds to the maximum Deconvolution Count, but the minimum lustre.

The maturity of the raw, unmercerised cotton has very little effect on the lustre of the mercerised material, though it exerts a great influence on the Deconvolution Count, and this is exemplified by the yarn series already quoted in Table IX. In this series of two-fold hosiery yarns spun and doubled under the same conditions from different varieties of cotton, and mercerised together under technical conditions, the Deconvolution Count of the Arizona cotton was 23, of the Sakel 63, but there was no marked difference in lustre. This result suggests that the value of a mercerised finish is not depreciated by the use of an immature cotton, a conclusion that is confirmed by the following experiments. (The use of immature cotton may of course lead to difficulties in spinning, and to the appearance of dead cotton neps in dyed materials.)

Separate lengths of 5-shaft Weft Satin of the same construction were all woven from the same Egyptian warp yarn (75% Sakel, 25% Brown), but with four different weft yarns varying only in variety of cotton—Egyptian Sakel, Egyptian Uppers, Long-staple Brazilian and Arizona Pima. The four lengths were sewn together and technically processed as follows—singled on the face side; bleached; mercerised; dyed, stentered, and cold calendered; glazed and schreinered. Other portions of the same cloth were beetled and hot calendered immediately following the mercerisation process. The Deconvolution Counts of yarns withdrawn from the mercerised cloths were as follows—

Weft Cotton			Deconvolution Count		Immaturity Count on Unmercerised Weft Yarn		
			Weft Yarn	Warp Yarn	% Normal	% Thin Walled	% Dead
Egyptian Uppers	..	...	73	—	61	32	7
Egyptian Sakel	...	...	71	59	59	34	7
Brazilian	...	...	52	—	44	39	17
Arizona Pima	..	...	38	57	36	49	15

These values are on the average much higher than those obtained from mercerised fabrics in plain weaves, a fact to be explained by the small constraint mutually imposed by opposite sets of yarns in the satin weave where there are relatively few intersections of warp with weft. The Deconvolution Counts on the warp yarns from the two samples examined in this direction are substantially identical, as was to be expected. The weft yarns, however, show a large variation, the Arizona cotton again yielding a very low result, although it was of a different year's crop from that used in the hosiery yarn (No. 151) which has been employed to a considerable extent in these investigations. Immaturity Counts made by Clegg's method on the four unmercerised weft yarns are included in the above table and the Deconvolution Count again falls as the percentage of normally mature hairs diminishes (cf. para. IIb).

The cloths were compared by practical finishers at various stages of processing, for example, in the pure mercerised finish, after glazing, after beetling, etc. and although the differences were often very slight, the sample with weft made from Arizona Pima cotton was generally selected as the best technical product, both in regard to lustre and feel. The experiment

certainly offered no evidence to support the view that a low Deconvolution Count resulting from the mercerisation of an immature cotton can be regarded as an indication of inferior mercerised quality in any technical sense.

The difficulty of interpreting Deconvolution Counts, and other laboratory measurements of mercerised quality, in terms of the technical requirements of a mercerised finish, is well illustrated by the following experiment in which the conditions were the opposite of those in the experiment just described—the cotton remained the same, whilst the mercerisation process was varied. The same high quality poplin cloth was singed, scoured, mercerised, bleached and dried without calendering in 200-yard lengths at each of five different works. No information was available on the precise details of the processing, which could therefore be expected to vary within the limits described by "normal trade practice." Table X contains the results of measurements and observations made on these five cloths (called Samples 1 to 5), for which the original composition and structure were in all respects identical.

Table X

Sample No.	Deconvolution Count		Moisture Absorption Ratio	Baryta Absorption Ratio	Reactivity Ratio	Bending Length	Order of Lustre	Order of Dyed Shade	% Warp Shrinkage
	Warp	Weft							
1	55	31	1.25	1.75	1.50	1.79	5 (Low)	2	12.7
2	51	28	1.24	1.88	1.65	2.92	1 (High)	4	12.7
4	49	22	1.24	1.70	1.50	2.52	Inter.	1 (Dark)	13.5
5	47	21	1.14	1.49	1.28	2.01	Inter.	5 (Light)	13.1
3	25	15	1.12	1.53	1.30	1.90	Inter.	3	15.4

The measurements will be considered in order as they occur in the table. The Deconvolution Counts on the warp yarns arrange the samples roughly in two classes—Nos. 1, 2, 4, 5 are all fairly high and not very different from one another, whilst No. 3 is much below these. The Deconvolution Counts on the weft yarns are all lower than the values for the corresponding warps, and it has already been pointed out that this is a usual feature of mercerised two-fold poplins. The order given by the weft yarns is the same as that given by the warps, so that even the small differences between Nos. 1, 2, 4, and 5 probably possess some significance. The values given for Moisture Absorption Ratio⁴ place the samples in the same order, but the classification is different since Nos. 1, 2 and 4 are relatively high and similar, whilst No. 5 is now classed with No. 3, both being much lower than the remainder; the Moisture Absorption Ratio is probably the most accurate of all the recorded measurements, a difference of 0.02 being experimentally significant. The Alkali (baryta) Absorption Ratio³ and the Reactivity Ratio¹ resemble the Moisture Absorption Ratio in so far as they class Nos. 1, 2, 4 together as similar and high, Nos. 5 and 3 together as similar and low; in both of these measurements—unlike Deconvolution Count and Moisture Absorption Ratio—Sample No. 2 is the highest of its group. Thus even the laboratory measurements cannot all be considered as measurements of the same quality, but the complexity of the problem increases when these are compared with the handle and appearance of the samples. The "bending lengths" of the materials are measures of their stiffness, which increases as this value rises.⁵

If Sample No. 1 were omitted, the bending lengths would result in the same classification as the absorption and reactivity ratios, for which high values would then correspond to stiff cloths; the first sample occupies, however, an entirely different position in an ordered rearrangement of this column from that occupied by it in any of the preceding columns, and although it yields high values of Deconvolution Count, Absorption and Reactivity Ratios it is the softest (least stiff) cloth. From inspection of the five materials they could easily be arranged in three classes according to their lustres, and this classification is given in the column headed "Order of Lustre." Sample No. 2 showed definitely the highest lustre, Sample No. 1 definitely the lowest, whilst the three remaining samples were of intermediate lustre, and could not be distinguished with certainty. This is a grouping showing no obvious relation to that obtained from the Deconvolution Counts, in which the low value of No. 3 is not reflected in the lustre properties, whilst the maximum and minimum lustres of Nos. 2 and 1 have no counterpart in the columns of Deconvolution Counts, Absorption or Reactivity Ratios.

When small samples of the five cloths were dyed together in the same bath, they showed large shade differences, and they could be arranged in a definite order of shade depth, which is recorded in the next column; this same order was maintained in each of three dyeings with different direct colours and in a dyeing with a sulphur colour. It is surprising that of all the observed qualities this is the most difficult to relate to any other quality or measurement. The shade variations are possibly determined in part by the "preparation" (scouring) of the cloths prior to mercerising, but the same order of dyed shade was obtained when small samples of the finished materials were rescourced with 1% sodium hydroxide solution under pressure in the attempt to eliminate any such variations. The bleaching (hypochlorite treatment) of the cloths was very mild, all samples exhibiting very low copper numbers and fluidities.

It is known that many of the properties of mercerised fabrics are affected to a greater or less extent by the tensions imposed during mercerisation, and the last column of the table records measurements of the shrinkage of warp threads when remercerised without tension after withdrawal from the cloth. The warp yarn was chosen for this measurement because this set of threads greatly preponderates in the poplin weave, and it is the lustre of the warp that determines the lustre of the cloth. Of all the recorded measurements these are the most nearly related to Deconvolution Counts, the relationship being an inverse one. In particular, the abnormally low Deconvolution Count of No. 3 is associated with an abnormally high shrinkage in loose remercerisation, which may reflect abnormally high tension in the original process. The low Deconvolution Count and the high remercerisation shrinkage could also be accounted for by very inferior penetration of the mercerising liquor into the material, but if this were the true explanation Sample No. 3 would be expected to occupy a lower place in the order of lustre. Although only an assumption, it seems probable that the main factor affecting the variation of Deconvolution Count in this series of materials is the tension during mercerising, rather than the impregnation or penetration of the liquor.

The most striking feature of the table is, however, the fact that samples Nos. 1 and 2 represent technical extremes in handle and lustre, the stiffest cloth having the highest lustre and *vice versa*. In spite of this they do not

differ significantly either in Deconvolution Count or shrinkage on remercerisation without tension. They are not significantly different in Moisture Absorption Ratio, and they only differ to a minor extent in Alkali Absorption and Reactivity Ratios.

It is evident that mercerisation factors of great importance for the technical qualities comprising a "mercerised finish" have relatively little weight in determining these laboratory measurements of mercerised quality, and from a strictly practical point of view, the description of any single measurement as the "Degree of Mercerisation" of the material is evidently undesirable.

VI—THE PRACTICAL USES AND LIMITATIONS OF DECONVOLUTION COUNTS

The results recorded in the last section are sufficient to illustrate the limitations in the practical interpretation of the measurement described in this paper. The Deconvolution Count cannot be used in any absolute way as a criterion of the practical success or value of technical mercerisation. Its utility is confined to an examination of the *uniformity of the mercerising treatment in material which is known to be of otherwise uniform quality*, or for establishing the cause of variations when other evidence is available to prove that they are not due to differences of structure in the original hairs, yarn, or cloth. In this case a large variation of Deconvolution Count can only be due to lack of uniformity in the wetting of the yarn by the mercerising liquor; a small variation of Deconvolution Count may be due to slight irregularity in the wetting or impregnation of the yarn, but if it is accompanied by pronounced differences of dyed shade it is more probably due to variations of shrinkage during mercerisation (tension variations).

The materials on which the measurement is of chief value from this point of view are the soft-twisted two-fold mercerised hosiery yarns, which generally give a high Deconvolution Count. The application of the measurement in the examination of mercerised hosiery yarns is dealt with more fully in the succeeding paper.

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26—THE EXAMINATION OF MERCERISED HOSIERY YARNS

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INTRODUCTION AND SUMMARY

The presence of undesired shade variations in dyed stockings knitted from mercerised yarn is a fairly common occurrence. The shade variation may consist of an abrupt change of colour from uniformly lighter in a part of the stocking to uniformly darker in another part, or it may consist of many comparatively short lengths of yarn differing in colour from the remainder of the material. These short lengths may be distributed in a superficially random manner through the fabric, or they may collect together to form regular and more or less bold patterns of stripes or diamonds. In either case they are often found on closer examination to recur regularly along the thread in periods characteristic of the hank structure.³

From the known effects of variations in mercerisation treatment on the dyeing qualities of cotton yarns it is to be expected that shade variations in mercerised hosiery will often be due to lack of uniformity in the yarn mercerising process, and critical methods for testing this possibility are very desirable. The methods used for this purpose in these laboratories are described in the present paper.

Shade defects that are periodic and characteristic of the hank structure are simpler to diagnose than those consisting of abrupt colour changes from one long length of yarn to another, such as might correspond to a difference between one hank and another, or one bobbin and another. The distribution of the irregularity in hank periods simplifies the problem since it precludes, as possible causes of the defect, variations in raw fibre quality and in the processes of spinning, doubling and singeing (gassing). This paper deals principally with the examination of such periodic irregularities.

The shade of dyed mercerised yarn is sensitive to many conditions in the mercerisation process itself, including the washing and drying operations. Two conditions that are well known to affect the shade are the efficiency of impregnation of the yarn with the mercerising liquor, and the tension applied to the yarn during mercerising, or the extent to which it is permitted to shrink in the process. Variations in either of these conditions within a hank must necessarily lead in greater or lesser degree to periodic shade variations when the material is subsequently dyed.

Variations in mercerised yarn caused by variations in the impregnation of the material with the mercerising liquor can be detected by a comparison of the extent to which the hairs in different parts of the yarn have deconvoluted

under the swelling action of the liquor. The variation can be expressed in a quantitative manner by measurements of Deconvolution Counts.⁴ When a dyed mercerised yarn shows a periodic colour variation associated with a large periodic variation in Deconvolution Count, the length of the period being characteristic of the hank structure, the results can be interpreted without ambiguity; the variability is certainly due to non-uniform impregnation of the hank with the mercerising liquor.

Variations in the shrinkage of yarn during mercerising may cause shade variations in subsequent dyeing that are accompanied by little or no difference in Deconvolution Count. A method for detecting such variations is described in this paper. It consists in remercerising the loose yarn under conditions which permit free shrinkage, and observing the regularity of shrinkage in this treatment. The interpretation of the result is based on the fact that variations of shrinkage in the first (technical) mercerisation must be reflected in complementary shrinkage variations in the second (laboratory) mercerisation; those parts of the yarn that originally shrank the more will subsequently shrink the less and vice versa. The experimental method employs a technique described in principle by Hegan and Shearer⁶ for the detection of tension irregularities in rayon yarns. By its means, a curve is automatically constructed on the yarn itself, wrapped in the form of a flat pad, such that the slope of the curve at any point is a measure of the shrinkage suffered by the yarn in the laboratory remercerisation.

Variations in shrinkage are thus shown by changes in the direction of the curve, and the coincidence or otherwise of colour and shrinkage changes is immediately apparent from an examination of the yarn pad. A pad of this kind, wrapped from a yarn mercerised without the application of tension or other constraint, and carrying a graphical record of its own shrinkage regularity during mercerising, is called for convenience the Shrinkage Diagram of the yarn.

A yarn containing variations caused by non-uniform impregnation with the mercerising liquor (variable Deconvolution Count) shows corresponding variations in its shrinkage on remercerisation without tension, the parts that were ineffectively impregnated, or in the extreme case entirely unaffected, by the original mercerising treatment shrinking more than those that had already been completely impregnated. When the variation is periodic the curve in the Shrinkage Diagram then shows a succession of sharp peaks and troughs coinciding with colour and Deconvolution Count changes (Fig. 3).

When the variation in the yarn is due to differences of shrinkage permitted in mercerisation, complementary differences of shrinkage are observed on remercerising the yarn without tension. A periodic variation of this kind again results in a Shrinkage Diagram showing periodic maxima and minima corresponding with colour changes, but with little or no change of Deconvolution Count. It is found in practice that differences of yarn shrinkage in the original mercerisation generally produce less abrupt effects than differences of impregnation, and in the former case the curve in the Shrinkage Diagram frequently shows a perfectly continuous wave form (Fig. 2) contrasting with the discontinuous peaks and troughs often shown in the latter case.

* Thus mercerisation irregularities due to both the common causes—faulty impregnation and irregular shrinkage—are detected by the Shrinkage Diagram and the two causes can generally be differentiated by means of Deconvolution Counts. The greater shrinkage is associated with the lighter

dyeing parts of the yarn, whichever cause is operative in producing shade irregularities after dyeing.

Periodic dyeing defects in hank mercerised yarns are occasionally attributable to local chemical degradation of the cellulose, and these are fundamentally distinct from the defects caused by variable swelling. The simplest way in which the local chemical attack of a mercerised hank can be conceived to occur is by a failure in the washing process following the souring operation that normally succeeds the mercerisation. More or less acid is left in a part of the hank, chemical modification of the cellulose occurs during subsequent drying or storage, and the resulting change in the affinity of the affected part of the hank for dyes causes a periodic dyeing defect in the thread. Such chemical attack of the yarn also affects its shrinkage on remercerising without tension, and therefore causes a periodic variation in the Shrinkage Diagram. In many cases, at least, the chemically modified yarn shrinks to a lesser extent than the normal, and since it invariably dyes a lighter shade in direct colours, the lesser shrinkage is associated with the lighter dyeing parts of the yarn. This state of affairs is the opposite to that found when the defects are due to faulty impregnation or variable shrinkage, where the greater shrinkage is associated with the lighter dyeing. Apart from this difference, the accepted tests for chemical degradation of cellulose can also be used to distinguish between dyeing irregularities caused in the actual mercerising operation, and those caused by chemical attack of the yarn.

Valuable confirmatory evidence is obtained from the so-called "Redyeing Tests." In these tests, samples of the unlevel dyed material are stripped of their original colour, scoured and redyed (*a*) on the material in this state, and (*b*) on the material after it has also been remercerised in the laboratory. If the treatment (*a*) results in a return of the shade irregularity distributed precisely as in the original dyeing, whilst the treatment (*b*) results in material of a level shade, the original irregularity must have been caused by some lack of uniformity in the conditions of the original mercerisation treatment. If both treatments (*a*) and (*b*) result in level dyeings, the defect must be due to an irregularity in the original dyeing process, or to the presence of some impurity on the yarn or fabric that was not removed by the dyer's preparation (scouring) and prevented the uniform absorption of dye. If, however, neither treatment (*a*) nor (*b*) results in a level dyeing, no unequivocal conclusion can be drawn without further investigation. The source of the defect may then be found at some stage other than the actual mercerising or dyeing, irregularities caused by chemical attack of the cellulose reacting, for example, in this way towards the Redyeing Tests. From the failure to produce a level dyeing after the yarn has been carefully remercerised it does not necessarily follow, however, that the original mercerisation was blameless. This case requires the special consideration that is given to it later in the paper (p. 7266).

When the shade irregularity consists of an isolated abrupt colour change in the stocking, the problem of deciding whether the variation occurred in the mercerising process is often difficult. This type of defect is generally characterised by a knot in the yarn at the shade change—an indication of a difference in dyeing quality between two different yarn packages (hanks, bobbins, etc.) joined at some stage in the winding or processing of the two-fold yarn, or at the knitting machine itself. It is usually possible to decide from a comparison between the Deconvolution Count of the knot itself and

that of the loose ends of yarn whether the join was made prior, or subsequent, to mercerising. When no external evidence is available, the difference may be due to the mixture of two different yarns mercerised independently—hence, probably differing both in the quality of the raw fibre and in the conditions of mercerising; or it may be due to a mixture of different yarns mercerised identically, or of the same yarn mercerised under two different sets of conditions; or finally, it may be due to accidental or deliberate variations within nominally the same spinning, the same doubling, or the same mercerising process. The best that can be expected from any laboratory examination is a decision whether the shade difference is fundamentally due to a difference in raw fibre, in yarn structure, in mercerising conditions, etc.

For this purpose, a comparison between the two differently dyed threads with respect to yarn counts, twist, and staple qualities is the first essential. If no difference is found in these respects, the two threads can be compared in Deconvolution Count and Remercerisation Shrinkage. When large differences exist in any of these properties the fundamental cause of the shade variation can then be established with reasonable certainty, and the conclusion checked by the Redyeing Tests. In many cases, however, the measurable differences are all small, and their significance is then uncertain. Apart from the inherent difficulties in the accurate measurement of staple qualities, this is due to the fact that measurements of the structure of yarn and fibre, and measurements of the "mercerised quality" of yarn, are not strictly independent. No method for describing the mercerised quality of cotton materials has yet been devised that completely separates the effects of the mercerisation treatment itself from that of the yarn and fibre structure.⁴ Similarly, such structural properties as yarn counts, staple length and staple fineness are evidently affected to some extent by variations in shrinkage during mercerising, as well as by other factors in that process. Small differences in any of these properties are therefore difficult to interpret, and chief reliance must be placed on the Redyeing Tests. The conclusions can then only be stated as probabilities.

Abrupt shade changes in dyed mercerised hosiery are sometimes attributed to differences in yarn singeing (gassing). The characteristic behaviour of variations produced by non-uniform gassing is considered in detail in this paper, where it is shown that differences of dyed shade caused by such variations are very greatly reduced by mercerisation.

EXPERIMENTAL

I—THE DECONVOLUTION COUNT

The measurement of Deconvolution Count, its significance, and the method of sampling yarn containing a periodic variation have all been described.⁴ The dyed yarn is first wrapped compactly on a steel rod, covered with strips of adhesive, transparent paper, and is then cut from the rod to yield a flat yarn pad in which the periodic shade variation is shown as a series of alternating light and dark yarn bands. These bands, held together by the paper backing, are cut out from the pad with scissors, and measurements of Deconvolution Count can then be made either on individual light and dark bands, or on a collection of light bands for comparison with a collection of dark bands. The following measurements were made, for example, on the yarn in five dark and five light bands chosen at random from a dyed mercerised stocking in which a regular colour pattern was caused by shade variations recurring at intervals along the thread equal to a characteristic hank period—

				Deconvolution Count					Deconvolution Count
Light Band No. 1	...			42	Dark Band No. 1	...			63
" " No. 2	...			37	" " No. 2	...			57
" " No. 3	...			32	" " No. 3	...			60
" " No. 4	...			41	" " No. 4	...			68
" " No. 5	...			35	" " No. 5	...			65
Mean	...	...	...	37	Mean	...	...	...	63

In such a case, where variations in dyed shade are consistently associated with large variations in Deconvolution Count, the shade irregularity is certainly due to imperfect wetting, or impregnation, of part of a hank with the mercerising liquor.

II—THE SHRINKAGE DIAGRAM

(a) Description and Use of the Diagram

The dyed yarn to be examined, for example, withdrawn from a stocking, is wrapped compactly on a steel rod about 6 inches long and 2 inches in circumference by means of the apparatus used for the measurement of the colour periods (see the first *Memoir* of this series,³ Fig. 1), and a line parallel to the axis of the rod is drawn on the surface of the wrapped yarn, as shown diagrammatically in Fig. 1. If the yarn is then unwound from the rod the ink line becomes broken up into a series of spots equally spaced along the thread at distances equal to the circumference of the rod, and the method described is designed to compare the shrinkages of all these consecutive and equal lengths when they are remercerised without tension.

For this purpose, the yarn unwound from the rod is immersed loosely in a mercerising liquor so that it can everywhere shrink freely, and is washed and dried. It is then wrapped back again under constant tension on a steel rod smaller than that employed for the first wrapping, the diameters of the first and second rods being as nearly as possible in the same ratio as the original to the shrunk (remercerised) length of the yarn. If the shrinkage of the yarn during remercerising were perfectly uniform, and if the diameters of the two rods were precisely in the specified ratio, the ink spots on the yarn would evidently collect together in the second wrapping so as again to form a straight line parallel to the axis of the rod. It is not usually possible to choose the diameters of the rods with such precision, and a slight deviation in the ratio of the diameters from the specified value causes the line of spots to spiral slowly round the second rod. If, however, the shrinkage of the yarn during remercerisation is not uniform changes must occur in the direction of this spiral line corresponding with changes in the shrinkage.

After the yarn has been wrapped back on the second rod its surface is covered with tape, and the yarn supported by its backing, is cut from the rod by a razor incision parallel to the axis, exactly as in the method of examining colour periodicities already described.³ The resulting flat yarn pad, carrying a graphical record of its shrinkage during remercerising, is called the Shrinkage Diagram.

Figs. 2, a, b, c, are photographs of the shrinkage diagrams of three dyed mercerised yarns free from any marked shade irregularity, and typical of the results to be expected from reasonably uniformly mercerised yarn. Fig. 2d is the shrinkage diagram of an undyed and *originally unmercerised* yarn, in

which, therefore, any irregularities in shrinkage during laboratory mercerisation can only be ascribed to yarn structure irregularities. The general angle made with the horizontal by the ink line in the diagram (the angle of spiral on the rod) is of no direct importance in the interpretation of the diagram, the important features of which are the *changes* in slope of the line, or its lack of smoothness. The line is not perfectly smooth in any of the examples illustrated in Fig. 2, and in both 2a and 2b abrupt changes of slope, producing a saw-tooth effect, can be observed at certain places; the shrinkage diagram of the mercerised yarn illustrated in 2c is nearly as smooth as that of the unmercerised yarn in 2d.

All the examples given in Fig. 2 are, however, very different from the shrinkage diagrams given in Fig. 3, and obtained from the mercerised yarns in typical "barred" or "striped" stockings. In both 3a and 3b the indicator line changes its direction at short periodically recurring intervals, sloping now downwards from left to right, and then upwards from left to right. Although the colour variation cannot be easily reproduced in the photographs, the original diagrams showed very clearly that the indicator line sloped always in the one direction on the dark bands and always in the other direction on the light bands, the peaks or troughs being coincident with colour changes.

The periods in these shrinkage curves are thus the same as, and coincident with, the periods of the shade variation. These periods were very near to 54 inches in 3a, and to 96 inches in 3b, and were thus both derived from the hank structure.³ The Deconvolution Count of the yarn illustrated in 3a varied periodically in the same way as its shade and shrinkage, a large difference existing between dark and light coloured bands. In this case, therefore, the irregularities were due to imperfect wetting of one place on the hank by the mercerising liquor, and the sharp peaks and troughs of the shrinkage diagram are often encountered when the defect is formed in this way. The Deconvolution Count of the yarn illustrated in 3b was the same in dark, as in light, bands, and the shade variation was not, therefore, due to imperfect wetting of the hank with the mercerising liquor. This irregularity was caused by differential shrinkage of one part of the hank during its original mercerisation, and the regular wave form of the shrinkage diagram is very common with such defects.

(b) Detailed Method for Making the Diagram

It has been stated that the ratio of the diameters of the two rods used in making a shrinkage diagram should approximate closely to the ratio of the original to the shrunk length of the yarn after remercerisation. If this condition is precisely fulfilled the *general* direction of the shrinkage curve in the diagram is parallel to the long edge of the rectangle, as in Fig. 3b. This condition is advantageous because the more closely it is approached, the more sensitive is the testing method to shrinkage variations in the yarn. In order to select a suitable pair of rods, it is therefore desirable to know the average shrinkage of the yarn to be tested on remercerisation without tension, and this is conveniently measured with the simple apparatus shown diagrammatically in Fig. 4a (plan) and b (side view).

A length of the yarn to be examined, measuring about 200 inches, is tied together at its ends, and the resulting loop A is passed round a glass hook B fastened in a wooden base-board C. The yarn passes over a glass guide D, and is held under tension by a weight of 50 grams (E) suspended from the end of the loop. The base-board carries a line F so placed that the length of yarn from the line round the hook B and back to the line is exactly 100 inches.

Two coloured threads are tied tightly on the yarn immediately above the line F, one on each half of the loop, a length of 100 inches being thus marked out on the yarn. The loop is removed from the apparatus and laid loosely in 7.5 *N* caustic soda solution (about 53° Tw.) containing 1% of Mercerol (wetting agent), where it is allowed to remain for five minutes. The caustic soda is poured off, the yarn lightly pressed and drained, and then covered with glacial acetic acid, with which it remains in contact for five minutes. Finally, it is washed free from the acid in hot water and dried in the steam oven. The remergerised yarn is replaced on the hook B, weighted as before, and arranged so that both the coloured ties (now separated by less than 100 inches on account of the shrinkage) fall between the line F and the hook.

The base-board carries a scale of inches and tenths, starting from the line F as zero, and extending for about a foot towards the hook. The distance of each coloured tie, one on each half of the loop, from the line F is noted, and the sum of these two distances gives directly the percentage shrinkage of the yarn.

The diameter of the steel rod used at this Institute for making the first wrapping is generally 0.60 inch, and the rod for the second wrapping can be selected from a series of 11, ranging in diameter from 0.53 to 0.55 inch in successive steps of 0.002 inch; this covers the shrinkage range from 8.3 to 11.7% in steps of 0.34%. By using rods of 0.58 and 0.62 inch diameter for the first wrapping, and the same series of smaller rods for the second wrapping, the shrinkage range that can be investigated is extended to include values between 5.2% and 14.5%; the remergerisation shrinkage of practically all mercerised hosiery yarns is covered by this range. All the rods used in this method of testing should be as uniform in diameter as possible. It is clear that any slight irregularity in the diameter of either rod used for making a shrinkage diagram must be reflected in the diagram itself, where the effect would be indistinguishable from that produced by an irregularity in the yarn shrinkage. This is not a serious consideration in the investigation of periodic irregularities in dyed yarns, where positive conclusions are only justified by the coincidence of shrinkage and colour periods. Much greater care would be necessary in the interpretation of non-periodic variations in the shrinkage diagram, unless they were clearly coincident with corresponding shade variations.

From the measurement of average shrinkage, the most suitable pair of rods is selected. The first wrapping, of yarn directly withdrawn from the stocking, is made on the larger rod with the apparatus illustrated in Fig. 1 of a preceding communication,³ modified in the following way to secure a better control of the winding tensions, necessitated particularly by the high extensibility of yarns remergerised without tension. The spring tension device E is used simply to clamp the yarn by tightening it until the thread is gripped. Between E and the rod A the yarn passes over two small, light pulleys not shown in the figure, and a weight is suspended on the yarn between the two pulleys; this weight is the same as that used in tensioning the yarn during the shrinkage measurements (50 grams). The clamp E is loosened to allow the weight to drop and thus form a long hanging loop of thread between the two pulleys. The yarn is again clamped when the hanging weight almost reaches the floor, and the resulting loop of yarn is wound up on to the rod. A further loop is then allowed to form by loosening the clamp; this in its turn is wound up on to the rod, and the whole wrapping is made in a series of such stages

under the constant tension imposed by the hanging weight, care being taken to avoid jerking the yarn during the operation.

When the wrapping is completed, a line parallel to the axis of the rod is drawn on the yarn surface in Indian ink with a straight-edge and pen. After this has dried, the yarn is rewound from the rod on to a rotating wooden rod of about four inches circumference, traversing it rapidly by hand. The yarn can then be slipped from this rod in the form of a small skein of 4 inches girth, and it is transferred to a support, conveniently consisting of a glass rod bent into the form **U**, on which it remains during its immersion in the mercerising liquor, treatment with glacial acetic acid, washing in water and drying. These operations are all carried out under the same conditions as those used in the shrinkage measurement. Finally, the yarn is wound back again on the smaller rod under the same constant tension as in the first wrapping. If the general direction of the line in the second wrapping is considered to be not quite satisfactory in relation to the axis of the rod, the yarn can be re-wrapped on a slightly smaller or larger rod as may be required.

The second wrapping—the shrinkage diagram—is backed with adhesive (rubber) tape, cut from the rod and pressed flat as described in the earlier paper.³

The length of yarn (100 inches) used in the preliminary shrinkage measurement, and the method of washing the remercerised yarn, are specially chosen. The length of specimen in the preliminary examination is such that it contains roughly a whole number of the common shrinkage period lengths found in hank mercerised yarns, and thus provides a reliable average sample. The shrinkage of a yarn on mercerisation is influenced by the precise conditions under which the material is washed free from the mercerising liquor. When water is used, an additional shrinkage occurs over and above that occurring as a result of the immersion of the yarn in the mercerising liquor. This additional shrinkage depends upon the temperature of the wash water, and probably upon the rate at which the mercerising liquor is washed out from the yarn. In order to avoid the necessity for controlling these factors, which might prove difficult, the first washing is done with glacial acetic acid, and the total shrinkage is then less than when water is alone used.

III—THE REDYEING TESTS

Useful evidence on the cause of shade irregularities in dyed hosiery yarns can be obtained by observing them when they are redyed following the discharge ("stripping") of their original colour. For the investigation of periodic colour variations a length of yarn sufficient to form a pad of the usual size is withdrawn from the stocking and wrapped into a small skein on a wooden rod about 4 inches in circumference. It is slipped from the rod, stripped of colour, and redyed. Hosiery colours can generally be stripped by boiling the yarn in a 1% caustic soda solution containing a little sodium hydrosulphite, though sufficiently complete removal of the colour is not always obtained by this process. In more difficult cases the yarn, after boiling with alkaline hydrosulphite, is washed and immersed for three to five minutes in an acid bleaching solution, approximately *N*/25 in hypochlorite, obtained by diluting a much stronger, stock hypochlorite solution with the necessary volume of roughly *N*/5 acetic acid. The yarn is then again washed and reboiled in the alkaline hydrosulphite solution. It may be necessary to repeat these alternate bleaching and boiling processes two or three times before a sufficiently complete removal of the original dyestuff is obtained. The yarn is then boiled for

one hour with 1% caustic soda solution, washed and immediately redyed. The direct dye Chlorazol Brown LFS is generally used in these laboratories for redyeing tests, the conditions of dyeing being—15 minutes in a boiling bath containing 0.02% of the dye *on the volume of liquor*, in the absence of added salt, and with a liquor to cotton ratio of about 260.

The redyed yarn is washed, dried, wrapped compactly on a steel rod, and formed into a flat yarn pad by the usual method. The comparison in shade levelness between the original and the redyed yarn is greatly facilitated when both are examined in the form of flat yarn pads. The laboratory processing of the material in the form of small skeins avoids the possibility of introducing dyeing irregularities with the normal hank periods if accidental defects occur during the stripping or redyeing process.

If the pad of redyed yarn is free from the periodic shade irregularity contained in the original material, the defect cannot be ascribed to faulty mercerisation. It will practically always be found in this case that the hosiery was dyed in the yarn, and not—as more usual—in the piece, and the source of the defect must then be sought in the hank dyeing process, or in the preparation (scouring) of the yarn for dyeing.

If the shade irregularity persists in the stripped and redyed pad, distributed along the thread exactly as in the original dyed yarn, a further length of thread is withdrawn from the stocking, stripped of colour, and boiled as already described. The small skein, washed with water and pressed out, is immersed in 7.5 *N* caustic soda and thoroughly impregnated with the alkali under conditions that permit of complete yarn shrinkage. The skein is then washed with hot water, redyed by the method already described, and wrapped into the pad form.

If the shade irregularity—persisting after simple stripping and redyeing—is completely eliminated, or very greatly reduced in intensity, by remercerising and redyeing, the source of the defect is to be sought in the original mercerisation process. If, however, redyeing after remercerisation fails to produce a dyed yarn of substantially level shade, it is not safe to conclude that the source of the defect must necessarily be sought elsewhere than in the original mercerising. Although it is natural to assume that a dyeing irregularity caused by some irregularity in the mercerising treatment should be effaced by careful remercerisation and redyeing in the laboratory, the assumption is not justified, and the realisation of this fact is of great importance.

The experiments described below were designed to determine whether shade differences caused by known extreme differences in mercerisation treatment could be effaced by remercerisation under uniform conditions. A hank of yarn was provided with three equidistant tie-bands such as to divide its circumference into three sections of about equal lengths. When the hank was stretched tightly on the stationary rollers of a mercerising machine, one section could be immersed in the caustic soda contained in the tray without wetting the remaining two-thirds of the hank. The section was mercerised in this way, and washed with water under conditions that prevented yarn shrinkage. The hank, removed from the rollers, was then dipped in the mercerising liquor, so that a second section of its circumference was alone wetted. This was allowed to shrink freely in the liquor, and the hank was then washed and dried, the remaining third of its circumference never having been in contact with the mercerising liquor. Such a hank contains periodically recurrent lengths of yarn (*a*) mercerised and prevented

from shrinking, (b) mercerised and allowed to shrink completely, (c) unmercerised, and if the yarn could be remercedised so as to yield a level shade in subsequent dyeing, it might be safely concluded that any mercerising irregularity that occurred in practice could be effaced by the same conditions of remercedising.

When yarn from this irregularly mercerised hank was dyed, and a pad prepared from it, a repeating pattern was obtained, shown diagrammatically in Fig. 5. The period of repeat is 54 inches of yarn, but each unit of the pattern contains three bands, namely, a band C of very light shade without lustre, derived from the unmercerised third of the hank circumference, a band B of very dark shade also without lustre, derived from the mercerised section allowed to shrink, and a lustrous band A of intermediate shade from the third of the hank that was mercerised without shrinkage. Fig. 6 is a photograph of the shrinkage diagram of undyed yarn from such a hank. Each wave in the periodic shrinkage curve is composed of three parts corresponding to the three treatments distributed round the hank circumference. The middle part of each wave is an almost horizontal line, and this corresponds to the lustrous yarn that was mercerised and prevented from shrinking. On the right of this the yarn has shrunk on remercedisation less than in the middle part of the wave, as shown by the rapid fall of the curve from left to right; this yarn was derived from the section of the hank originally mercerised and allowed to shrink. On the left side of the wave the line falls rapidly from right to left, indicating that this portion of the yarn has shrunk more during remercedisation than that in the middle of the wave. It corresponds to the third of the hank which was originally unmercerised.

When yarn from this hank was remercedised and dyed under the conditions described earlier as a part of the routine for redyeing tests, that is, conditions permitting complete shrinkage in all parts of the yarn during remercedisation, the resulting shade was far from uniform.

The bands of originally unmercerised yarn then dyed to approximately the same shade as those of yarn originally mercerised and allowed to shrink, but the section of yarn that had been prevented from shrinking in the original mercerisation retained to a considerable extent its lustre, and its tendency to dye a lighter shade. If Fig. 5 represents the original distribution of colour in the dyed yarn, the distribution after remercedising without tension would be similar, except that the B and C bands would run together as a wide dark and non-lustrous band, whilst the A band would remain relatively light and lustrous. The remercedisation can easily be repeated several times by dipping the loose yarn for a few minutes alternately in relatively large bulks of mercerising liquor and water. If this is done, the bands of yarn (B and C) originally unmercerised and mercerised without tension can be made practically indistinguishable in dyeing quality, but even after 12 successive treatments the bands originally mercerised and prevented from shrinking (A) still retain appreciable lustre, and still dye somewhat lighter than the remainder of the yarn.

In the above experiments, the conditions of remercedisation were such as to permit complete shrinkage. Alternatively, the yarn can be wrapped on a rigid frame, immersed in the mercerising liquor, and washed with water whilst still on the frame; this process of alternate immersion in the mercerising solution and water can be repeated as often as desired, and the yarn is thus submitted to a number of successive mercerisation processes, under conditions which prevent yarn shrinkage. When this is done and the material

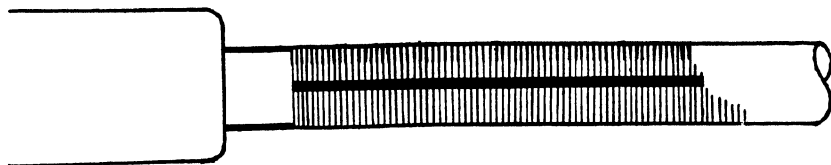
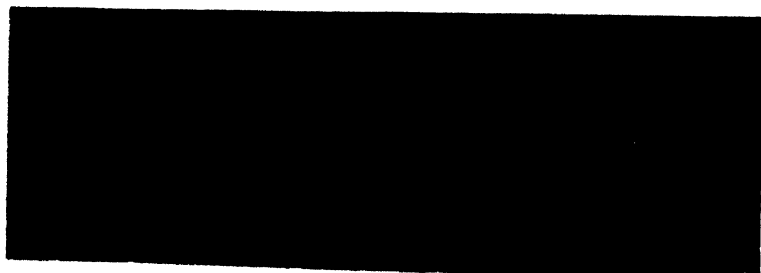


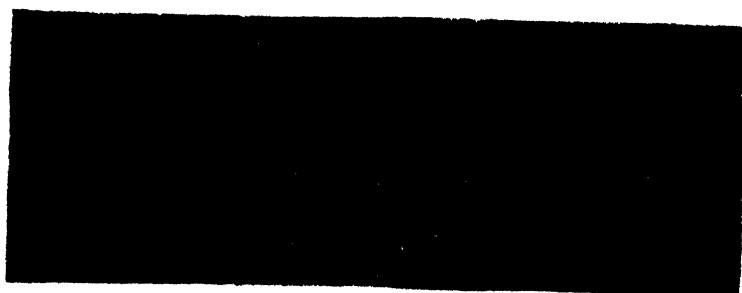
FIG. 1



Shrinkage diagrams of reasonably level dyeing mercerized yarns (*a*, *b* and *c*) and of an unmercerized yarn (*d*).



(a)



(b)

FIG. 3.
Shrinkage diagrams of unevenly dyed mercerised yarns.

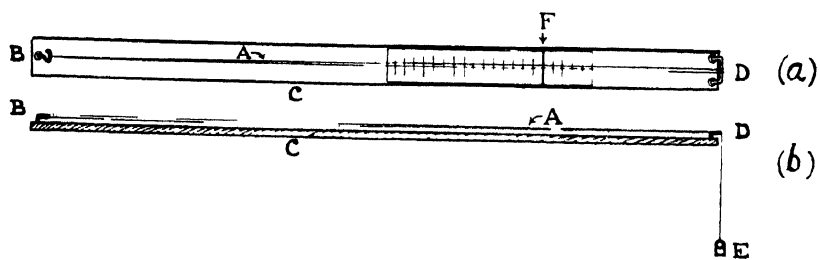


FIG. 4

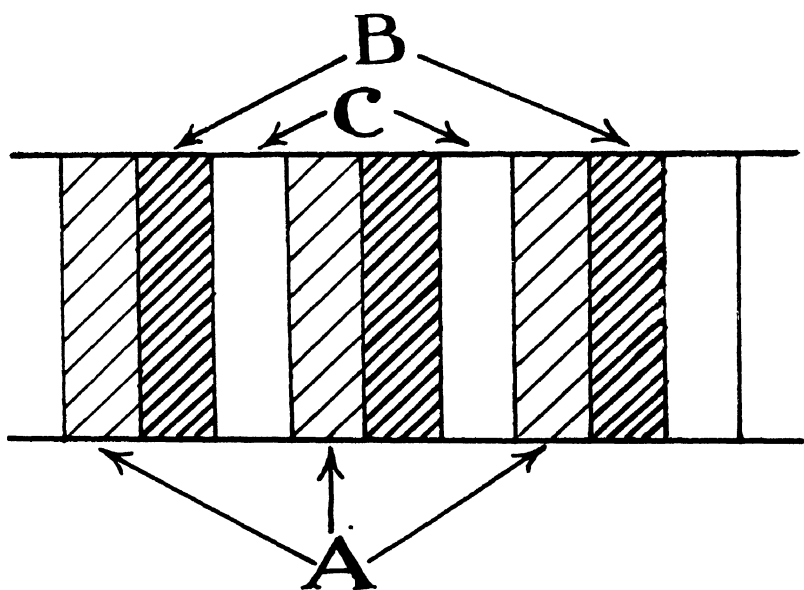


FIG. 5

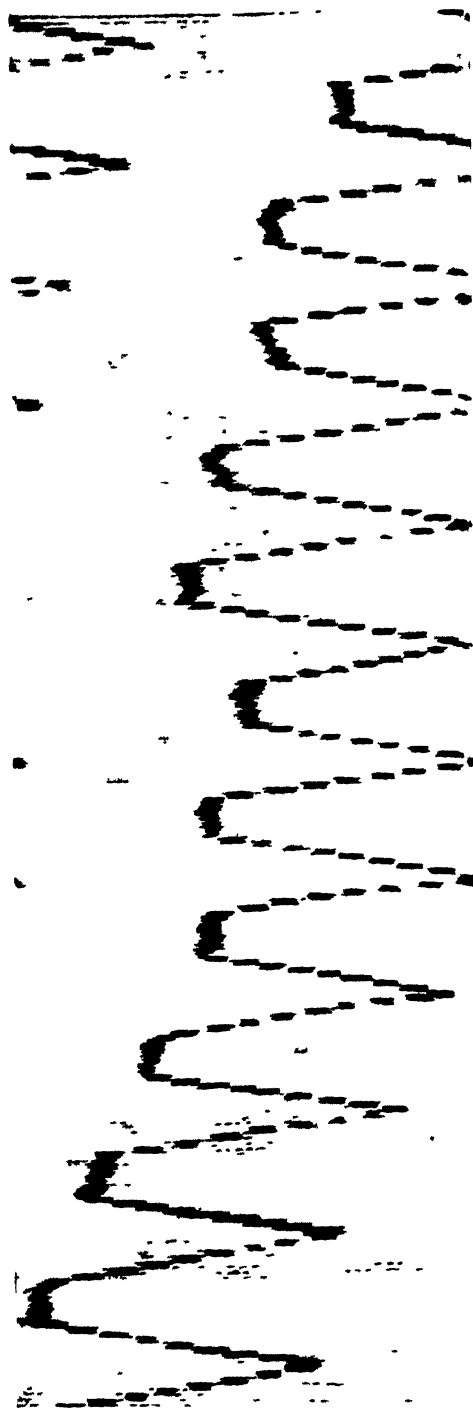


Figure 1

Shrinkage curve of bank prepared is described on the opposite page

subsequently dyed, the yarn bands corresponding to originally unmercerised places in the hank and those corresponding to the places mercerised without being allowed to shrink, become practically indistinguishable in shade and lustre; the bands originally mercerised and allowed to shrink, although they acquire some lustre as a result of remercerising under the described conditions, remain, however, darker in shade even after the yarn has been remercerised many successive times on the frame. In the yarn pad represented diagrammatically in Fig. 5, the A and C bands coalesce to form one wide lustrous band dyeing a lighter shade than the B bands, which are also to some extent lustrous. Thus, by means of the two remercerising treatments described, the unmercerised portion of the yarn can be made to dye the same shade as either of the two mercerised portions—allowed to shrink and prevented from shrinking—but neither treatment is capable of making the *two differently mercerised portions* equal in dyeing quality.

A number of successive treatments on the yarn mercerising machine itself, in which the hank was alternately impregnated with caustic soda and washed, and—during each impregnation stage—alternately stretched and relaxed many times, also failed to produce a uniformly dyeing yarn from this originally very irregularly mercerised hank.

The experiments described above illustrate the irreversible character of the mercerisation process; the qualities conferred on yarn by particular conditions of mercerising are retained to some extent through subsequent mercerising treatments under other conditions. For example, yarn mercerised and prevented from shrinking dyes a lighter shade and possesses higher lustre than the same yarn allowed to shrink freely during mercerising. But when yarn already mercerised under the former conditions is remercerised under the latter, it retains the imprint of its history, namely, a higher lustre and a lighter shade after dyeing than yarn mercerised once only, and that without constraint on its shrinkage.

The application of these results to the interpretation of redyeing tests shows that dyeing irregularities in hosiery yarns may in fact be due to irregular conditions of mercerising even though they cannot be effaced by remercerising under uniform conditions. Frequently, however, such irregularities are greatly reduced by remercerising and redyeing, and when the original variations are not extreme, a substantially level dyeing is obtained.

One case occurs not infrequently in practice in which the original variation is of an extreme kind, and this is worthy of special notice. It is the case in which a portion of the hank has for some accidental reason completely escaped contact with the mercerising liquor. The hank is then composed mainly of yarn mercerised under tension, but contains some completely unmercerised yarn. A dyed wrapping from such a hank shows light non-lustrous streaks recurring at 54-inch intervals, characterised by a much lower Deconvolution Count than the darker dyeing yarn. After the wrapping has been stripped and mercerised without tension the bulk of the yarn in it has been mercerised twice, once under tension and once loose, but the streaks recurring at 54-inch intervals have been mercerised once only, and that without tension. From what has been said, it will be seen that when the yarn is redyed, the bulk of it will remain more lustrous, and will dye a lighter shade than the originally unmercerised streaks. A reversal of colour effect therefore occurs as a result of the remercerisation, the original wrapping of lustrous yarn containing periodically recurrent non-lustrous and *light* streaks being changed to a wrapping of relatively lustrous yarn containing

non-lustrous *dark* streaks. This is a very characteristic behaviour, and provides a valuable indication in testing; when it is observed it may be concluded with reasonable certainty that the original defect was due to a wetting failure in the caustic impregnation, a conclusion that can be checked by Deconvolution Counts. This type of defect cannot be levelled by remercerisation without tension, and a better result is obtained by wrapping the yarn on a rigid frame, and immersing it alternately in the mercerising liquor and water several times before thorough washing and redyeing.

For the purpose of the redyeing tests it is desirable to use a dye, and dyeing conditions, that are likely to display prominently any variations in the mercerised quality of the material. Skeins of yarn in which mercerising irregularities had been deliberately produced were dyed with about 40 different direct colours under the same dyeing conditions, and with one direct colour under a variety of different conditions. An examination of the resulting dyeings, wrapped in the form of yarn pads, showed that Chlorazol Brown LFS dyed as described on page 1262, was as favourable for displaying mercerising irregularities as any of the conditions used in this series of experiments.

Mixtures of dyes would be expected to yield, on the average, less level dyeings on non-uniformly mercerised yarn than single homogeneous dyes. A variation in mercerised quality might be expected to react slightly differently on the various components in a mixture of dyes, and the resulting unevenness would then consist, not only in a difference of depth or intensity of colours, but also in a difference of actual colour quality. Examples of unlevel mercerised stockings are occasionally encountered in practice which show this effect, for example, stockings dyed a grey shade and containing streaks, not simply of lighter grey, but of bright blue yarn.

The following is a mixture that has been used in these laboratories for dyeings in 1% shades designed to give maximum prominence to mercerisation irregularities—

Chlorazol Sky Blue FFS	...	...	...	...	0.71%
„ Red KS	...	...	...	...	0.17%
„ Fast Yellow BNS	...	...	...	...	0.12%

This mixture can be dyed so as to yield a fairly neutral grey, but the actual shade obtained varies enormously with the precise conditions of dyeing, and variations in the mercerisation of the yarn may, under suitable conditions of dyeing, result in large colour differences. Favourable conditions for obtaining strong colour contrasts are, for example, the dyeing of a 1% shade for 15 minutes at the boil, from a bath containing 10% of soap on the weight of the cotton with a liquor to cotton ratio of 20 to 1.

IV—DYEING IRREGULARITIES CAUSED BY CHEMICAL ATTACK OF THE COTTON

Periodic shade irregularities in dyed mercerised hosiery caused by chemical attack of the yarn are commonly due to the incomplete removal of acid from hanks that have been soured after mercerising. Any oxidising treatment of the yarn in hank form, such as bleaching, would naturally introduce the possibility of periodic defects caused by oxidising attack of the cotton, but stockings are not normally manufactured from bleached yarns.

The behaviour in the tests already described of yarns containing shade irregularities due to chemical attack of the cotton is the following—In dyeings with direct colours, the attacked parts are relatively light in shade. The colour difference persists in the yarn after stripping, scouring and redyeing,

and it remains very prominent after stripping, remercerising, and redyeing. There is little difference in Deconvolution Count between lighter and darker dyeing parts of the yarn, but the colour differences may be accompanied by corresponding variations in the shrinkage diagram; these are often in the opposite sense to the variations caused by mercerisation irregularities, the lighter dyeing yarn shrinking less than the darker dyeing.

The presence of chemically degraded cotton can be confirmed by a redyeing test with a basic dye, and by the silver staining test. For the basic redyeing, a sample of the yarn is stripped and boiled by the method already given, redyed, and wrapped into a pad for comparison with the redyeing in a direct colour (Chlorazol Brown LFS). In these laboratories the redyeing is carried out for 15 minutes at the boil in a relatively large volume of a 0.02% solution of Methylene Blue 2BS, and the yarn is washed in cold water after dyeing. Confirmation of the presence of chemically attacked cotton is obtained when the relatively light bands of yarn in the pad dyed with the direct colour correspond to relatively dark bands in the basic dyed pad.

Harrison's silver staining test⁵ affords a convenient qualitative indication of the enhanced reducing properties characteristic of chemically attacked cotton. If the yarn is dyed a medium or heavy shade it is desirable to strip the colour, but this must be done without the use of a hot alkaline treatment, which destroys the reducing properties of the modified cellulose. Sufficiently complete colour discharge can generally be obtained by treating the yarn with a hot hydrosulphite solution to which no alkali has been added; complete stripping is not necessary, but a short treatment with an acid hypochlorite solution under the conditions described earlier can be used if the shade is not sufficiently reduced by the hydrosulphite. The solutions used for the silver staining test as carried out in these laboratories are—

No. 1—Silver nitrate—8 grams in 100 c.c. of water.

No. 2—Sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$) 200 grams } With water
Sodium hydroxide 200 grams } to 1 litre

For each gram of cotton, the quantities used are—1 c.c. of solution No. 1, 2 c.c. of solution No. 2, and 40 c.c. of water. Solution No. 1 is first diluted with half the specified volume of water, solution No. 2 with the other half, and the diluted solutions are then mixed with stirring, No. 1 being poured into No. 2. A sample of the stripped yarn sufficient to make a pad is boiled for five minutes in this mixture, washed first in solution No. 2 diluted 5 to 10-fold, then with water, and finally dried and wrapped into a pad. Black or relatively dark bands of yarn corresponding in size and distribution with the light bands in the original dyed yarn confirm the presence of chemically attacked cotton.

When sufficient of the material is available, complete confirmation can be obtained by a comparison of the fluidities in cuprammonium solution of the lighter and darker dyed parts of the yarn.²

V—EXAMINATION OF ABRUPT SHADE CHANGES

Abrupt shade changes in dyed mercerised stockings almost invariably occur at knots in the yarn. Unlike the periodic irregularities caused by variability within one hank, they are due to differences between one hank (or other yarn package) and another; the two different hanks may or may not have been mercerised in the same operation, the folded yarns may or may not have been doubled as a part of the same batch, and the single yarns may or may not have been spun from the same mixing. Thus, in addition to the possibility of actual variations within one process producing hank to hank

differences, there exists a large number of stages at which accidental or deliberate mixing can occur of yarns that differ in some quality affecting their dyeing properties. It is fairly generally realised that the avoidance of abrupt shade changes in a batch of stockings demands strict adherence to the yarn produced in one spinning, one doubling, and one mercerising operation, but the material passes through so many different hands between the bale and the finished goods that this very desirable control is not easily ensured.

It is usually possible to decide whether the knot marking the shade change was inserted before or after mercerising. If the former, the loose "tails" of the knot must have been mercerised without tension; they are then devoid of lustre, and have a somewhat shrivelled appearance. If the latter, they were mercerised under tension, and do not differ in appearance from the bulk of the yarn. A still better criterion is obtained from a comparison of Deconvolution Counts on the knot itself and on the loose ends of yarn ("tails" of the knot). If the knot was inserted before mercerising the portions of the cotton hairs within the knot have little opportunity to deconvolute, partly because the penetration of the mercerising liquor into a tight knot is difficult, and partly because of the mechanical resistance to swelling and deconvolution in such a compact structure. The loose tails of the knot would, however, have received a treatment almost ideally favourable to deconvolution from the point of view both of easy penetration and absence of constraint on the swelling.

In order to illustrate this, lengths of an unmercerised two-fold yarn were knotted together, wrapped on a rigid frame, and mercerised in 7.5 *N* caustic soda. The mercerised yarn, after being washed and dried, was cut, and the cut ends again knotted together. A comparison was then made between knots inserted before and after mercerising, the following Deconvolution Counts being obtained—

The knot made before mercerising	...	...	...	17
The loose ends of this knot	...	...	...	85
The knot made after mercerising	...	...	...	52
The loose ends of this knot	...	...	...	55

For the knot inserted after mercerising no significant difference exists between the knot and its ends, as was to be expected, whilst a very great difference exists for the knot inserted before mercerising. The three Deconvolution Counts of 17, 53 and 85 are similar to those that would be obtained for the same cotton mercerised (*a*) in the form of a very tightly twisted yarn, (*b*) in the form of a soft hosiery yarn, (*c*) as unspun hairs.

For the determination of Deconvolution Count on a knot, the necessary hair fragments are obtained by pressing the knife down on the knot itself. The fragments are more variable in length than those obtained by cutting yarn wrappings, but abnormally long fragments can be neglected during counting. The number of fragments available for examination is also less than that constituting the normal sample, but the difference between the knot and the loose ends is so great when the yarn has been joined before mercerisation that no great accuracy is necessary.

If an abrupt shade change occurs at a knot shown by this method to have been made before mercerisation, the cause of the dyeing difference must be sought at some stage prior to mercerising. In the majority of cases, however, the knot is found to have been inserted after mercerisation, and this affords no evidence bearing on the origin of the dyeing difference.

After the knot has been examined, the structure of the yarns on each side of the shade change, and the quality of staple in the cotton composing them are next examined. The counts and twists of the yarns are measured, whilst, with regard to the quality of staple, the mean or effective length, the length distribution, the mean hairweight, the hairweight distribution, and the immaturity can all be compared quantitatively¹. If large differences are found in any of these properties between the two yarns of different shades, the laboratory investigation can be carried no further, and the shade change is sufficiently accounted for. If no difference, or only a small difference, is found in any of these yarn or fibre characteristics it does not necessarily follow that the two yarns are identical in the sense that the shade difference is not attributable to any difference in the quality of the fibre from which the yarns were made. In the group of Sakel and similar cottons from which hosiery yarns are frequently spun, differences in dyed shade may be accompanied by differences in the ordinary staple qualities too small to be of definite diagnostic value; this is true whether the dyeing is made on a lightly scoured unmercerised ground, on a mercerised ground, or on a severely scoured (boiled under pressure with caustic soda) unmercerised ground. Once such yarns have been mercerised there is at present no direct way of proving that the difference was inherent in the materials before spinning.

If no definite variation is found in yarn or fibre structure, measurements of Deconvolution Count and Remercerisation Shrinkage are made on the two yarns, the simple apparatus illustrated in Fig. 4 being used for the latter measurement. Large differences in either of these can be interpreted with safety as indicating differences in the mercerisation of the yarn, a conclusion that is, however, only justified when the yarn structure and staple measurements mentioned above yield no evidence of pronounced differences. When the differences in Deconvolution Count and Shrinkage are small, no safe conclusions can be drawn since their interpretation depends on the identity or otherwise of the original cotton, itself incapable of unambiguous test when only small staple differences are in question.

The two yarns are then compared by the Redyeing Tests, and the results of these are most easily judged if the redyed material is finally wrapped into pads. For this purpose small skeins of yarn are prepared in which the two threads are alternated several times in lengths sufficient to form bands about an inch wide in a pad made from them. These skeins are stripped of their original colour and redyed with Chlorazol Brown LFS (*a*) immediately after stripping and boiling, and (*b*) after stripping, boiling, and remercerising without tension, as described in Section III. The redyed materials are wrapped into pad form, and, for comparison with them, a pad is prepared containing the two original dyed yarns alternated in about 1 inch bands. The results of the redyeing tests are interpreted in the following sense—

(i) *The Shade Difference is obliterated by Redyeing without Remercerising.* Its cause cannot then be attributed to differences in yarn structure or in cotton staple, to chemical attack of the material, or to differences in impregnation or tension during mercerising. When the dyeing has been done in the yarn form, the most probable source of the shade variation must be sought in that process. In the more usual case of dyeing in the piece, differences can only be due to the presence of some impurity on the yarn that escaped removal by the hosiery dyer's preparation, but was removed during the laboratory stripping and scouring. For example, technical mercerising

liquors accumulate impurities from the grey cotton which may be precipitated on the material at some later stage, and cause shade differences in the dyed goods if they are not sufficiently well scoured before dyeing. It is not usually possible to obtain positive evidence on the cause of shade changes that can be corrected by simple stripping and redyeing.

(ii) *The Shade Difference, not removed by Redyeing alone, is eliminated, or greatly reduced, by Redyeing after Remercerising.* The cause must then be sought in the mercerising process.

(iii) *The Shade Difference is reversed by Redyeing after Remercerising without Tension, the original darker dyed yarn becoming the lighter and vice versa.* This can also be due to variations of a particular kind in the mercerisation process (cf. Section III), but the original shade difference is then always accompanied by a large difference in Deconvolution Count.

(iv) *The two Yarns show a similar Shade Difference whether they are merely Redyed, or Remercerised and Redyed.* The cause must then be attributed either to chemical attack of the cotton, or to a difference existing in the cottons before mercerising, such as a difference in staple qualities. Of these two alternatives the former can be directly tested by reliable methods already described.

In the above system of testing by means of redyeings, the existence of differences inherent in the raw cotton is deduced by the elimination of other known and possible sources of variation. When supporting evidence cannot be obtained by measurement of staple length, fineness, etc., the indications of the redyeing tests can only be regarded as pointing to the probable origin of differences. Variations may also occur in the mercerisation process that would be correctly located by the redyeing tests, but that cannot be confirmed by more specific methods of testing; such are shade differences caused by differences of temperature in the drying of the mercerised yarn, or in washing the yarn on the mercerising machine.

Special consideration is given in the next section to the possibility of changes in dyed shade being caused by variable yarn singeing or gassing.

The methods described above form the scheme of routine testing used in these laboratories for the examination of abrupt shade changes in dyed mercerised hosiery. The large number of possible causes of this defect, and the general lack of detailed information regarding the many processes employed in the production of the goods, sometimes renders it impossible to fasten responsibility to a particular process, much less to a particular stage of a process, by means of the present resources of laboratory investigation.

VI—THE EFFECTS OF VARIATIONS IN SINGEING (GASSING)

When the same yarn is singed under different conditions, variations of colour may be seen in the undyed yarn, the more severe conditions of singeing producing a darker shade, or a more scorched appearance. If dyeings are then made on the singed materials without any previous scouring treatment, corresponding variations in dyed shade might be expected purely on account of the differences in colour of the ground. When the yarn is submitted to a reasonable scouring treatment in preparation for hosiery dyeing, such as boiling in soap solution, the differences in shade between the undyed yarns are greatly reduced, though samples singed under different conditions may still show appreciable shade differences after dyeing. Such differences of dyed shade are not due to variations in the colour of the undyed ground, but to

actual chemical differences in the cotton produced by the variable heat treatment. This is shown by the fact that the darker yarn (more severely singed) in the undyed state becomes the lighter yarn after dyeing with direct colours, but remains the darker after dyeing with unmordanted basic colours. The reversal of colour effect on changing from a direct to a basic dye is similar to that observed in a comparison of yarns chemically attacked to different extents with oxidising liquors, such as hypochlorite solutions, under suitable conditions. The following experiments were carried out to determine whether variable singeing was to be regarded as a probable source of abrupt shade changes in dyed mercerised hosiery.

A 2/40's Egyptian hosiery yarn was singed on an ordinary gassing frame in three different operations of varying degrees of severity, described as light, normal and heavy gassing. The normal gassing was carried out in accordance with the general practice at the mill where the experiments were made, the light gassing was accomplished by lowering the flames, and the heavy gassing by running the yarn twice through the machine. The differences in shade of the three undyed samples were clearly visible, that between the extremes of gassing (light and heavy) being very striking, and such as would certainly cause the samples to be rejected in the doubler's inspection room.

A circular fabric was knitted from the gassed yarns, using all three samples alternately in the same material so that a definite striped pattern was produced, clearly visible owing to the differences of grey shade caused by variations in the gassing process. This fabric was soap scoured, and then dyed in a large number of direct and sulphur colours. The following observations were made—

The differences between the extremes of gassing (light and heavy) caused a noticeable difference of dyed shade in nearly all the dyeings, the originally darker yarn (heavily gassed) being lighter than the originally lighter yarn (lightly gassed). For smaller differences of gassing—for example, the difference between normal and heavy—the corresponding differences in dyed shade were small and by no means striking, the effect being barely detectable with many of the direct colours. Chlorazol Blue BS showed the effects of variable gassing as prominently as any dye examined, and this colour is recommended for illustrating the behaviour.

When the fabric was dyed with the basic dye Methylene Blue 2BS the difference in shade between the gassing extremes was also clear, but the more heavily gassed yarn then dyed the heavier shade, an opposite behaviour to that of the direct and sulphur dyes.

The yarn samples gassed with varying degrees of severity were next mercerised in hank form, incorporated in knitted fabric, scoured and dyed with a variety of colours as before. The shade difference between the undyed yarns was very greatly reduced by mercerisation, so that light and heavily gassed yarns, strikingly different before mercerisation, could barely be distinguished after mercerisation. After the material had been dyed, the effect of variable gassing on the dyed shade could no longer be detected; no difference of shade could be observed with any of the colours, even between those yarns that had suffered the extreme gassing difference.

It must be concluded that variation in singeing is an improbable cause of abrupt shade changes in dyed, *mercerised* hosiery. It could only afford a satisfactory explanation of the defect on the assumption of singeing differences so great as to lead to immediate detection, and rejection, by the doubler. If the possibility of singeing differences as a cause of abrupt shade

changes is envisaged, the scheme of testing described in the previous section is extended to include a redyeing with Methylene Blue 2BS. The dyeing is carried out as already described, and the shades of the two yarns are finally compared by means of a pad containing alternating bands of the two, precisely as in the technique for comparison of shades in redyeings with direct colours. An explanation of shade differences on the basis of singeing variations cannot be upheld unless a reversal of colour effect occurs on passing from the direct to the basic dyeing. The existence of such a reversal is not, however, in itself proof of a singeing variation, since it can also result from differences in general chemical attack of the cotton, or from differences inherent in the raw cottons before spinning. It is to be expected that differences in singeing sufficiently great to cause shade variations after mercerising and dyeing would be detectable by differences in the surface hairiness of the yarns wrapped in a suitable form for inspection.

The changes produced in the dyeing properties of cotton materials by singeing are presumably due to chemical alteration—possibly oxidation—of the cellulose, but they cannot be detected by the usual tests for chemically attacked cellulose. Thus, the fluidities of the ungassed and the three gassed yarns described above in cuprammonium solution only showed very small differences of doubtful significance, in spite of the fact that this measurement is very sensitive to ordinary forms of chemical attack in cellulose, such as by bleach liquors, acids, etc. It therefore seems likely that the chemical modification of cellulose produced during singeing is restricted to a very thin outer layer of the yarn, which may exert a preponderating influence on the colour of the dyed thread, but only a very small influence on the properties of the thread *as a whole*, such as its copper number or fluidity. This view has received confirmation from measurements made on the pile of singed fabrics of the velveteen type. In order to obtain a uniform pile, such fabrics are sheared, that is, the tips of the pile yarns are cut off, and the shearings obtained are in the form of a fine powder consisting of hair fragments from the outermost surface of the pile. The fluidity of such shearings is found to be greatly affected by singeing the material prior to the shearing process. In one case examined, the fluidity of shearings from the unsinged fabric was 8.0 in 0.5% cuprammonium solution, whilst the same fabric singed yielded shearings with a fluidity of 18.5.

It has been seen that differences in dyed shade caused by variable gassing are largely eliminated when the yarns are mercerised between gassing and dyeing. The variations in dyed shade caused by ordinary forms of chemical attack of cotton, such as by process liquors, cannot be corrected by mercerisation. This difference in behaviour may be due to the fact that the processes of shrinking and stretching to which materials are submitted during mercerisation presents them with a fresh surface, so that the chemical modification caused during singeing, and localised in the original surface layer, no longer exerts its effect on the shade of the dyed thread.

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27—A CONTRIBUTION TO THE THEORY OF MILLING— PART 2

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In Part I of this paper,¹ a method for measuring the scaliness of wool fibres was described, but attempts to derive a strict relationship between scaliness and milling properties failed to meet with success. Although in the case of extreme types, such as merino wool and mohair, a direct relationship between scaliness and milling properties was observed, with more closely related wools, such as Wensleydale, Oxford Down and Southdown, the order of scaliness was exactly the inverse of the order of milling properties. The preceding measurements of scaliness were carried out under ordinary atmospheric conditions of humidity, and to this extent any comparison with milling properties is suspect. With this difficulty in mind, the scaliness of a few wools has since been measured under water. The method of experiment was precisely similar to that already described, except that the 50 fibres were mounted to form a bow on a *glass* bridge, while the face cloth, on which friction measurements were made, was attached to the plane face of a rectangular glass block. During an experiment, the face-cloth and fibre-bow were submerged in water contained in a small glass tank carried by the same inclined plane used in earlier experiments. Measurements were carried out, and the results calculated, exactly as before, giving the data summarised in Table I.

Table I

Wool					Scaliness	Fibre Diameter (μ)
1	Tasmanian Super-quality Merino	...	...	...	119.5	17.0
2	Cape Merino, 70's	...	...	...	69.5	19.3
3	Southdown, 56's	...	...	...	56.2	29.0
4	Australian Merino, 60's	...	...	...	49.1	24.7
5	Romney Marsh	...	...	...	47.3	32.2
6	Oxford Down	...	...	...	46.9	38.1
7	Corriedale	...	...	...	43.4	23.6
8	Leicester	...	...	...	42.9	33.6
9	Wensleydale	...	...	...	33.8	36.4
10	Mohair	...	...	...	15.7	37.0

In all cases the scaliness measured under water is greater than in ordinary air, the increase in the case of Tasmanian super quality merino wool being surprisingly great. Increased scaliness is due, no doubt, to the increased flexibility of wet fibres, which permits more intimate embedding with the fibres of the face cloth. This factor must, of course, play an important part in the milling process, and measurements of scaliness carried out with wet fibres are definitely to be preferred to those obtained in ordinary air, for correlation with milling properties. Contrary to expectation, the order of

scaliness of the different wools is not the same for the two sets of measurements, and there is a possibility that the increased scaliness observed in water is not due solely to more intimate fibre contact, but to increased scale projection caused by fibre-swelling. The former factor is probably the more important, but there is as yet no convenient method for studying the effect of swelling on scale projection.

The chief importance of the preceding results, however, is that they again reveal but an imperfect correlation between scaliness and milling properties. With extreme types, such as merino wool and mohair, the order of scaliness is the order of milling efficiency, but the same inverse relation between scaliness and milling properties is again evident in the case of Wensleydale, Oxford Down and Southdown wools. In view of these results, there can be little doubt that, although the presence of surface scales may be essential for milling to be possible, the different milling properties of various wools are not determined solely by different degrees of scaliness. Actually, a precise relationship between scaliness and milling was not to be expected, because the determining cause of shrinkage—scaliness—is a surface property and the external surface of a given weight of wool is inversely proportional to the fibre diameter. For the same degree of scaliness, the milling properties of different wools should increase with their quality, *i.e.* with decreasing fibre diameter. The mode of operation of the surface factor has already been illustrated in the preceding paper in the case of merino and Southdown wools blended in various proportions. It will, however, be recognised that the effect of wool quality is not capable of reconciling the contradiction under discussion, because Wensleydale wool, which is the coarsest and least scaly of the three wools, possesses the best shrinkage properties. On the other hand, Wensleydale wool possesses the longest fibres and it thus becomes important to study the influence of fibre length on milling properties.

If fibre travel, as argued by Ditzel² and Shorter,³ is intimately connected with milling shrinkage, length of fibre must influence the process, but it is difficult to decide from first principles whether milling properties will increase or decrease with increasing fibre length. Experiments were therefore carried out with Wensleydale wool to determine the relationship between fibre length and milling shrinkage. A Wensleydale top having an average fibre length of 13.1 cms. was selected, part being cut by hand to a shorter length and again converted into top. The average fibre length of the cut wool was 5.5 cms. The longer wool was converted into 1/4.6's yarn, having five turns per inch twist, while the shorter wool was made into yarns of the same count with 4.8 and 7.3 turns per inch twist. These several yarns were woven with 24 picks per inch into a 2/20's white American cotton warp with 24 ends per inch, the weave being 2/2 twill. In order to avoid temperature variations during milling, the three cloths were milled with soap in the fulling stocks, shrinkage-time curves being obtained by measuring the area of a marked rectangle in each piece at intervals. Typical data are given in Table II.

Table II

	Wool			Count of Yarn		Twist (turns/inch)		Strength of Yarn (ozs)		Percentage Shrinkage in Area in 4 hours
Long	1/4.60	...	5.0	...	60.0	...	13.4
Short	1/4.75	...	4.8	...	40.4	...	7.6
"	1/4.78	...	7.3	...	58.0	...	5.3

It is evident that long wool causes more rapid shrinkage than short wool, whether the yarns be of the same strength or of the same twist. The influence

of fibre length on milling properties is obviously very great, and it is no doubt this factor which gives the coarse Wensleydale wool of inferior scaliness its superior milling properties compared with the finer and more scaly Southdown wool.

Besides the three factors so far considered, there can be no doubt that crimpiness in wool must affect the amount of shrinkage which can be realised in milling. The longer fibres produced during yarn production by the removal of crimp will strive to recover their original wavy form. Some shrinkage due to this cause occurs in piece scouring, but further shrinkage of the same kind during milling is dependent on the occurrence of fibre travel and the freeing of fibres from mutual hindrance to recovery. Thus crimpiness must be regarded as a factor of secondary importance in any attempt to derive a comprehensive view of the milling process, but its mode of operation is, as will be seen later, essentially similar to the determining mechanism of milling shrinkage.

As regards the influence of gross structural differences on the milling properties of different wools, the argument is now complete. The determining factor in milling is the surface scale structure of the fibres, but the rate and extent of shrinkage due to this cause are not determined solely by different degrees of scaliness in various wools, but by differences in fibre length, fineness and crimpiness in addition.

MILLING CONDITIONS

With any one wool, it is well known that the rate of milling shrinkage is determined by milling conditions, particularly as regards temperature and the milling agent used. Although the action of milling agents has been the subject of many investigations and much discussion, no finality appears to have been achieved. This aspect of the milling process is by far the most interesting and a complete re-examination of the problem has been attempted.

Shrinkage as a Function of the pH of the Milling Agent

It is well known that under constant mechanical conditions, the rate of shrinkage of a fabric is least in water and increases with increasing acidity or alkalinity of the milling agent. In order to give some degree of precision to this common observation, a complete study of the influence of the pH of the milling agent on the rate of shrinkage has been made. $4\frac{1}{2}$ yards of a scoured Cheviot cloth, weighing approximately $2\frac{3}{4}$ lb., were used in each experiment. Two areas, each 1 yard square, were marked out on the piece with coloured cotton thread, the precise area of each square being determined whenever necessary by making three measurements each of length and width at equal intervals apart. The cloth was immersed in 10 litres of the milling agent under investigation, contained in an enamel vat, and allowed to soak for 24 hours. At the end of this time, the cloth was removed and centrifuged to remove excess solution. After the areas of the marked squares had been measured, the cloth was transferred to the fulling stocks, which are definitely to be preferred for experimental work where reproducible results are required; in a milling machine it is exceedingly difficult to maintain adequate control over the temperature factor. At the commencement of fulling, 2 litres of the solution with which the cloth had attained equilibrium were added gradually to the cloth as it revolved in the stocks. After one hour, the cloth was removed and the areas of the two marked squares measured. Milling was then continued for a further hour, the areas being again measured, and so on. In

order to compensate for the evaporation of water during the course of an experiment, an addition of 250 c.c. of the milling solution was made at the end of two hours' and four hours' milling. The preceding conditions of milling were repeated in every experiment, with the result that strikingly reproducible data were obtained. These are given in the following table, together with the pH , measured potentiometrically, of the milling agent, *i.e.* the solution with which the wool was in equilibrium. Each value for the percentage reduction in area is the mean of the results for the two marked squares.

Table III

Milling Agent	<i>p</i> H		Percentage Reduction in Area in—					
			1	2	3	4	5 hours	
Sulphuric acid	0.50	...	19.1	32.8	42.9	48.1	53.3	
	1.06	...	16.9	27.6	37.1	45.8	50.7	
	1.66	...	15.1	24.7	33.9	41.4	45.8	
	2.99	...	11.4	19.7	26.0	32.1	36.8	
	3.93	...	9.0	16.4	25.0	28.6	33.5	
Water (2 changes)	..	8.29	...	9.4	16.0	23.3	28.8	33.6
Sulphuric acid	..	8.57	...	10.2	17.6	23.1	27.9	33.9
Water	8.97	...	11.0	20.9	28.4	35.4	40.2
Potash soap	9.92	...	17.1	32.6	40.8	47.0	50.2
Sodium carbonate	...	10.30	..	13.4	22.9	31.9	39.1	42.9

In Fig. 1 the preceding results are graphically reproduced. Since no data are available for pH values between 4 and 8, it may seem a little arbitrary to represent the shrinkage as being independent of pH between these limits. That this is not the case will become apparent from later argument, but it should be mentioned that the final pH of a milling solution is extremely difficult to predetermine in large-scale experiments of this kind. The magnitude of the difficulty will be apparent from the fact that in the two experiments where the final pH was 3.93 and 8.57, the amounts of sulphuric acid added to 10 litres of water containing 2½ lb. of wool were 11.8 and 5.7 c.c. of pure sulphuric acid, respectively. Small variations in the amount of adsorbed soap retained by the cloth after scouring of course play a very important part in determining pH in the neighbourhood of neutrality.

The curve of Fig. 1 seems to indicate that milling is most rapid at about pH 10 on the alkali side of neutrality, but the evidence for a critical pH is inconclusive. The maximum rate of milling is given by soap, which may not facilitate shrinkage merely by increasing the pH of the milling agent. For this reason, a second series of milling experiments was carried out with a new supply of Cheviot cloth of different weave. 5½ yards of cloth, weighing about 3½ lb., were used in each experiment, the mode of procedure being exactly as before. The data obtained are recorded in Table IV.

Table IV

Milling Agent	pH		Percentage Reduction in Area in—				
			1	2	3	4	5 hours
Water ...	8.96	...	8.7	13.8	17.3	20.6	24.4
Caustic soda ...	9.02	...	7.7	13.9	17.4	22.7	26.1
Sodium carbonate	10.04	...	7.2	13.9	19.1	25.7	29.6
"	10.20	...	8.7	15.6	21.2	26.2	29.7
Caustic soda	12.32	...	6.6	11.0	14.4	18.9	20.5
"	c 13	...	3.7	7.2	11.6	13.5	16.8
Potash soap	9.94	...	11.3	20.1	25.7	31.3	36.8

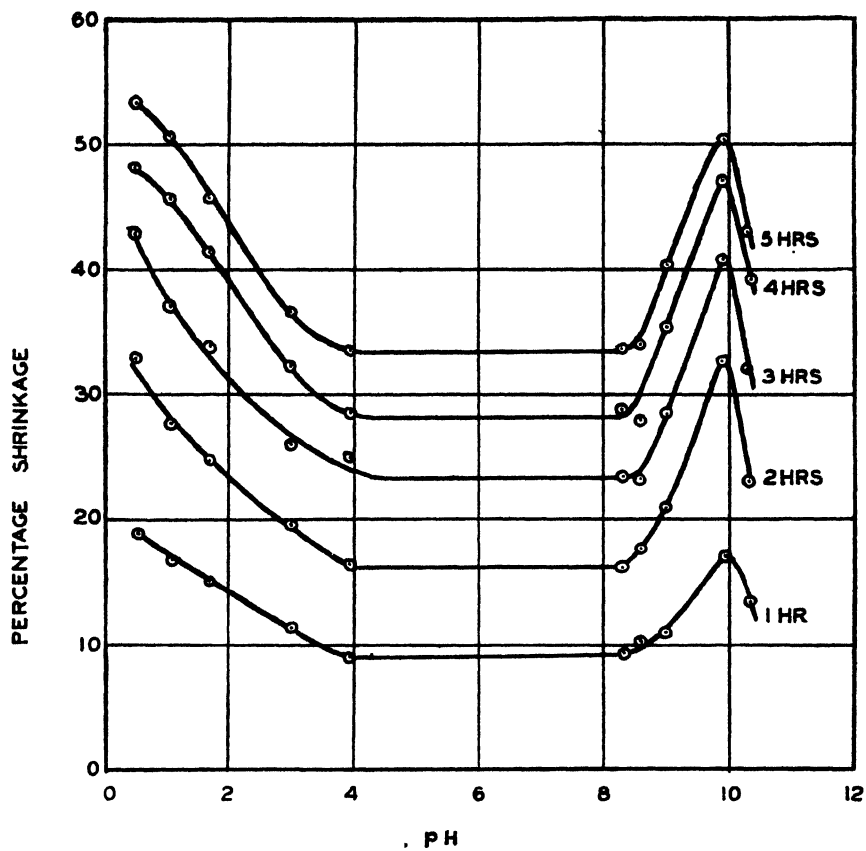


FIG. 1

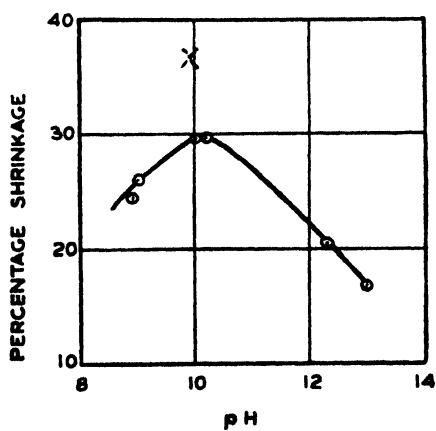


FIG. 2

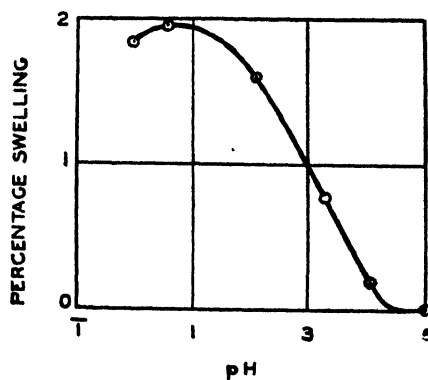


FIG. 3

The amount of shrinkage which occurs in five hours' milling is plotted against pH in Fig. 2, and when attention is restricted to soda and caustic soda, it is still apparent that milling is most rapid at about pH 10.0. The data for potash soap, shown separately, indicate that soap has a specific action in facilitating milling shrinkage, independent of the pH of the medium. No success can, therefore, attend any effort to replace soap as a milling agent by soda or caustic soda. It need hardly be said that the preceding deduction has no reference to milling in the grease with soda, which is essentially soap milling.

The Relation between Fibre Swelling and Milling Properties

Apart from such incidental interest of the preceding results, they serve to give precision to the known fact that milling shrinkage takes place more rapidly in acid and alkaline media than in water. Since the swelling of wool fibres is greater in acid and alkali than in water, it has come to be supposed that such agents promote shrinkage by their action in increasing swelling or turgidity. Actually, the parallel is a close one, as is revealed by a comparison of Fig. 1 with Fig. 3, which illustrates the swelling of wool fibres in sulphuric acid solutions of varying pH . Referred to water at pH 5.5, swelling commences at pH 4.0, the very pH at and below which the rate of shrinkage increases. In alkaline media, the parallel is not quite so precise because, although swelling increases continuously with increasing pH , milling reaches a maximum rate at pH 10.0. Nevertheless, there is a sufficient parallel between swelling and milling for it to have been supposed that fibre-swelling in some way determines the rate of shrinkage. Doubt as to the validity of this hypothesis was first aroused by Davidson's determinations⁴ of the swelling of cotton in water at different temperatures. He found that swelling was a minimum at 45° C., and in view of the many broad similarities between the two fibres, wool and cotton, it is a little curious that Harrison⁵ should have found that the rate of milling with soap or acid is most rapid at 46°–49° C. If wool is similar to cotton in showing a minimum swelling in water at about 45° C., the rate of milling should, by analogy with the properties of wool in acid and alkaline media, decrease instead of increasing with rise of temperature. A study of the swelling of wool fibres in water at different temperatures is evidently capable of giving an unequivocal decision as to the part played by fibre-swelling in the milling process. Interest in the investigation is not limited to its relation with milling, and experimental results and procedure have therefore been recorded in more detail than might otherwise be necessary.

The swelling of wool fibres in water can be calculated from the following formula, previously employed by King⁶ and Davidson⁴—

$$S = \frac{100 (\alpha V_w + V_A - V)}{V}$$

where S = the percentage increase in volume of the wool.

V = the specific volume of wool in benzene.

V_A = the apparent specific volume of wool in water.

V_w = the specific volume of water.

α = the weight of water adsorbed by 1 gram of wool.

Thus three sets of data, none of which is available, are necessary for the determination of the swelling of wool fibres in water at different temperatures.

(a) Specific Volume of Wool in Benzene at different Temperatures

With a view to generalising the results, experiments were carried out on five wools—60's Australian Merino, Wensleydale, 56's Southdown, Corriedale, and Mohair. These were purified by successive extraction with alcohol, ether and water, and small samples, varying in weight from 1.6 g. to 4.6 g., according to the character of the wool, were taken for experiment. The dry weights of the samples were determined by exposure to phosphorus pentoxide for 14 days *in vacuo*. Following the determination of dry weight, each wool was packed into a glass tube of about 20 c.c. capacity, the tube being sealed at one end to a length of capillary of 0.7 mm. diameter, the other end being closed. The five tubes so prepared were attached in parallel to a Töpler pump fitted with a phosphorus pentoxide tube. After evacuation of the whole system, the wools were allowed to dry for three months. At some distance from the bulb, the glass capillary was then sealed off and detached from the pump. The sealed end was afterwards broken under benzene, which had been freshly distilled over sodium after a preliminary drying over calcium chloride and over sodium. In this way the wool was immersed in dry, air-free benzene and the capillary tube was then cut off at about $\frac{3}{4}$ inch above the bulb. A reference mark was engraved on the capillary, and the weight of the tube containing the wool and filled to the mark with benzene, was determined at different temperatures. During weighings, the tube was, of course, fitted with a cap to prevent loss of benzene by evaporation. At the end of the series of determinations, the wool was dissolved out of the tube by means of caustic soda solution, and the bulb calibrated by filling with dry benzene and adjusting to the reference line at different temperatures before weighing. From data obtained in this way, the following results were calculated. Although density determinations were carried out at 5° C. intervals from 20° to 60° C., the relationship between specific volume and temperature was found to be linear for each wool, so that only three density values need be quoted in each case.

Table V

Temperature °C.	Specific Volume in Benzene of				
	Southdown 56's	Wensleydale	Corriedale	Merino 60's	Mohair
25.0	0.7657	0.7667	0.7651	0.7641	0.7665
40.0	0.7665	0.7680	0.7668	0.7655	0.7680
55.0	0.7672	0.7692	0.7686	0.7670	0.7695

According to King,⁶ the specific volume of a 60's merino wool at 25° C. was found to be 0.7692, a value slightly in excess of all values given in the preceding table. The difference may be due to the fact that in our experiments the wool was completely freed from air by evacuation with a Töpler pump, whereas King appears to have used a less drastic method of evacuation.

(b) Apparent Specific Volume of Wool in Water at Different Temperatures

After determining the dry weights of 2–5 g. samples of the same five wools as before, they were again packed into 20 c.c. bulbs, which were afterwards sealed to previously calibrated capillary tubes of approximately 0.7 mm. bore and 1 metre length. The dilatometers so prepared were filled with water in the following manner. A glass tube, similar to the one shown in Fig. 4,

was filled with freshly-boiled distilled water and then sealed at A to a mercury-sealed tap in direct communication with the Töpler pump. The dilatometer containing wool was sealed to the apparatus at B and the water in the tube then frozen by means of a paste of solid carbon dioxide and acetone. At this stage, the whole apparatus was evacuated. The tap connecting the dilatometer with the pump was then closed, the freezing mixture removed and the ice allowed to melt. Dissolved air released from the water was pumped off after the water had again been frozen, and the procedure was repeated until the system was entirely air-free. This accomplished, the apparatus was removed by sealing off between the pump and the tap. Water was then allowed to run from the side-tube into the bulb containing the wool, filling being completed by breaking the seal and opening the tap to the air. Finally, the dilatometer was cut away from the side-tube and tap at the upper end of the capillary. As it was not intended to carry out swelling measurements at temperatures higher than 65°C. , the bulb was immersed in water at 80°C. for 20 minutes to expel superfluous water and then allowed to cool. The tip of the capillary was sealed off as soon as the level of the water, on cooling, had receded far enough for this to be possible. Very little air was thus

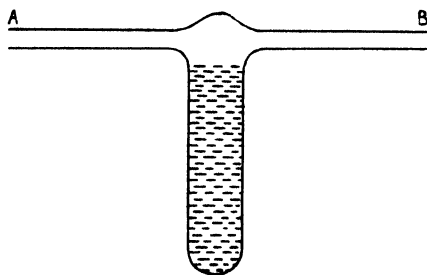


FIG. 4

included in the system. Readings of the height of the water level in the dilatometer at different temperatures were made on a scale, graduated in millimetres, which was attached to the capillary from the reference point upwards. At any one temperature, the height of water became constant after 20 minutes and readings were taken after this time. The length of the capillary was too great for complete immersion in the thermostat, and determinations were carried out with the dilatometer immersed exactly up to the reference mark engraved on the capillary close to the bulb. Corrections for the temperature of the emergent column of water were afterwards applied to the data on the assumption that the temperature of the water in the capillary was that of the room. In view of the low thermal conductivity of water, no serious error is involved in the assumption, as will be apparent from the series of check experiments. Readings of the height of water in the capillary were taken at 0°C. and at 5°C. intervals from 20°C. to 65°C. When the temperature had attained 65°C. , readings were taken at 10°C. intervals on a falling temperature scale, but no hysteresis could be detected.

At the end of each series of observations, the weight of water in the dilatometer was determined as follows—The bulb was cooled, and the greater part of the empty capillary drawn off after sealing, so that the rest of the dilatometer could be weighed. Afterwards, the sealed end of the capillary was cut off at a distance of approximately $\frac{3}{4}$ inch above the reference line, dried and weighed. After dissolving the wool with caustic soda solution, the clean, dry bulb was weighed. From this series of observations, knowing the dry weight of the wool, the weight of water present could be calculated.

The volume of the bulb and the coefficient of expansion of the glass were determined by weighing the bulb, filled with water up to the reference point at different temperatures. The data necessary for the calculation of the apparent specific volume of wool in water at different temperatures were then complete.

The procedure so far described was followed with all five wools, but in the case of the last two to be examined, Mohair and Wensleydale wool, a check was made as follows. After weighing the wool and water in the shortened, sealed dilatometer, the capillary was cut off a little way above the reference line, and the bulb, containing wool and water, was used for further experiments. The level of the water was adjusted to the reference point at different temperatures, the bulb and its contents being then weighed. These determinations, together with those obtained in the calibration of the bulb with water, provided an independent means of calculating the apparent specific volume at different temperatures. The results obtained for the five wools are given in Table VI. As regards Mohair and Wensleydale wool, two sets of values are given, the second set relating to the series of check experiments described above.

Table VI

Corriedale			Australan Merino 60's			Southdown 56's		
Temp °C.	Apparent Specific Volume		Temp. °C.	Apparent Specific Volume		Temp °C.	Apparent Specific Volume	
16.1	0.7134	...	0.0	0.7084	...	0.0	0.7064	
26.4	0.7185	...	14.2	0.7148	...	15.5	0.7142	
29.9	0.7193	...	25.0	0.7191	...	25.3	0.7180	
35.0	0.7209	...	30.0	0.7205	...	31.3	0.7200	
39.5	0.7229	...	34.8	0.7225	...	37.6	0.7217	
44.8	0.7247	...	40.8	0.7244	...	44.8	0.7238	
49.8	0.7265	...	45.6	0.7265	...	49.8	0.7248	
53.7	0.7280	...	49.3	0.7274	...	55.1	0.7271	
57.4	0.7294	...	55.2	0.7293	...	59.1	0.7291	
		...	59.8	0.7296	...	65.0	0.7312	
		...	64.3	0.7291	...			
		...	68.8	0.7289	...			
Mohair						Wensleydale		
Temp °C.	Apparent Specific Volume					Temp. °C.	Apparent Specific Volume	
0.0	0.7071	0.7073	...			0.0	0.7086	0.7082
15.2	0.7138	0.7133				13.3	0.7142	0.7138
25.9	0.7177	0.7177				25.8	0.7190	0.7189
30.3	0.7194	0.7194				30.9	0.7211	0.7107
34.4	0.7208	0.7208				35.9	0.7226	0.7224
39.6	0.7226	0.7224				40.4	0.7243	0.7242
45.1	0.7249	0.7247				45.2	0.7261	0.7259
50.5	0.7267	0.7265				50.6	0.7278	0.7277
54.5	0.7280	0.7280				55.5	0.7295	0.7289
59.4	0.7296	0.7295				59.3	0.7304	0.7299
64.8	0.7315	0.7311				64.0	0.7323	—

It is interesting to note (Fig. 5) that the relation between apparent specific volume and temperature is not linear as in the case of cotton, but is represented by a smooth curve. The actual values of the apparent specific volume at any one temperature vary very little from one wool to another, and the change in apparent specific volume with temperature follows the same course with different wools. In Table VII, values are given for the apparent density and specific volume of the five wools at 25° C. The mean apparent density is 1.3926, in excellent agreement with that given by King,⁶ namely, 1.3924 (d. 25°/4°).

Table VII

Wool	Apparent Sp. Vol. at 25° C.	Apparent Density d. 25°/4°
Australian Merino, 60's ...	0.7189	1.3910
Wensleydale... ..	0.7187	1.3914
Southdown, 56's	0.7177	1.3934
Corriedale	0.7176	1.3935
Mohair	0.7174	1.3939

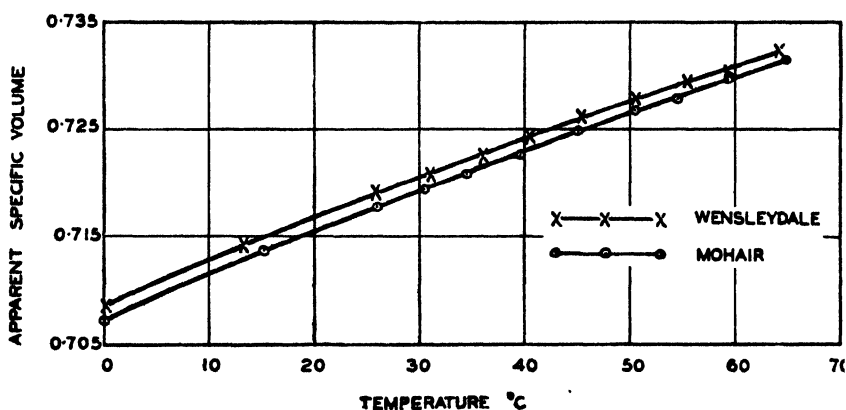


FIG. 5

(c) Variation with Temperature of the Combining Capacity of Wool for Water

The chief difficulty confronting any attempt to determine the amount of water adsorbed by wool from saturated air at different temperatures is that of preventing actual condensation of water on the wool. With a view to overcoming the difficulty, the following method of experiment was adopted. Approximate 0.25 gram samples of the wools to be used were purified in the usual way by extraction with alcohol, ether and water. The wool was then suspended from a silica spiral, provided with an axial reference point in the form of a silica fibre sealed to the coil at its upper extremity. Before use, the spiral was calibrated according to the method recommended by McBain. Its sensitivity, as deduced from the linear calibration curve, was 4.7 cm. per gram. Since the extension of the spiral was read to 0.0001 cm. by means of a travelling microscope, it was possible to detect a 0.01% increase in the weight of the wool. During an experiment, the spiral was

suspended from the hook A in the apparatus shown in Fig. 6, the dry weight of the wool being determined by streaming air dried by calcium chloride and phosphorus pentoxide through the system by way of tubes B and C. After

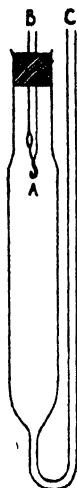


FIG. 6

determining the dry weight at room temperature, the apparatus was clamped in a vertical position within a thermostat at 20° C. Water was afterwards introduced through the side tube C until the surface of the water was about 6 cm. from the wool. The tubes B and C were then closed and the adsorption of water by the wool followed by reading the extension of the silica spiral at intervals. A typical set of results is given in Table VIII.

Table VIII			
Time (hours)			Extension of Spiral (cms.)
1.7	...	...	1.935
5.5	...	...	2.015
8.4	...	...	2.037
11.7	...	...	2.053
25.0	...	...	2.076
34.8	...	...	2.076

In this way it was possible to construct a curve showing the rate of approach of the wool to equilibrium, so that even when condensation of water did occur, it could always be detected and the true amount of adsorbed water determined by extrapolation of the well-defined curve representing the initial stages of water adsorption. When equilibrium had been attained at any temperature, the apparatus was withdrawn from the thermostat, water was removed from the tube by suction at C, and filtered room air was then drawn through the apparatus to dry the wool partially. Water was afterwards introduced into the system and a new determination of the amount of water adsorbed made at a higher temperature, and so on. The results are summarised in Table IX.

Table IX

Temperature °C.		Percentage by Weight of Water adsorbed by		
		Southdown, 56's		Australian Merino, 60's
20.0	...	32.2	...	32.2
24.4	...	32.3	...	31.1
29.6	...	29.9	...	30.7
35.4	...	29.2	...	30.4
40.4	...	29.0	...	30.2
50.6	...	29.6	...	30.1
53.9	...	29.9	...	30.3
59.4	...	30.0	...	30.4
67.4	...	30.6	...	30.5

No great degree of precision can ever attend attempts to determine directly the amount of water adsorbed from saturated air, but the general validity of the preceding data is supported by more recent experiments carried out in conjunction with C. A. Cooper, using a technique similar to that of Urquhart and Williams.⁷ Leicester wool was employed and the data available refer to desorption conditions at 97.5% relative humidity.

Table X

Leicester Wool

Temperature °C.		Percentage by Weight of Water adsorbed
25.0	...	29.3
30.0	...	28.4
35.0	...	28.1
40.0	...	27.6
45.0	...	28.2
50.0	...	29.6
55.0	...	30.2

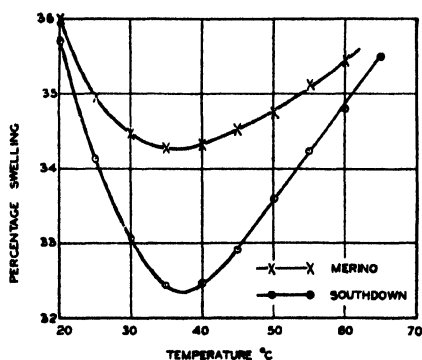


FIG. 7

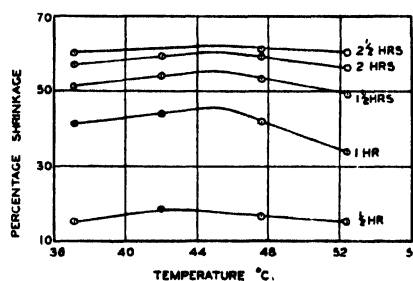


FIG. 8

Since water is adsorbed by wool with evolution of heat, a rise of temperature at constant relative humidity should be accompanied by a fall in the amount of water adsorbed. Up to 40°C., this deduction is true, but according to the preceding data, a rise of temperature is accompanied by an increase in the amount of water adsorbed at temperatures above 40°C. It seems clear that at high temperatures, just as in the case of cotton, the expected decrease in the affinity for water is compensated by the creation of new surfaces available for adsorption. Further evidence in support of this conclusion has been derived from a totally different series of experiments, which will receive discussion in connection with another aspect of the milling process.

As already indicated, the swelling of wool fibres in water at different temperatures may be calculated from the preceding three sets of data. The results so obtained are summarised in Table XI, illustrated by Fig. 7.

Table XI

Temperature		Percentage Increase in Volume of		
°C.		Southdown, 56's		Australian Merino, 60's
20	...	35.72	...	36.00
25	...	34.12	...	34.96
30	...	33.07	...	34.46
35	...	32.44	...	34.27
40	...	32.48	...	34.32
45	...	32.91	...	34.52
50	...	33.60	...	34.75
55	...	34.23	...	35.13
60	...	34.81	...	35.43
65	...	35.80	...	—

With both wools, swelling is at a minimum at 37° C.

As the temperature is raised, therefore, the swelling of wool fibres in water first decreases and then, beyond 37° C., increases. On the other hand, Harrison⁵ claims to have found that the rate of milling shrinkage, using soap or sulphuric acid as the milling agent, first *increases* with rise of temperature and then, beyond 46° to 49° C., falls. Hence as regards change of temperature, an increasing rate of milling is accompanied by decreased swelling, and *vice versa*; whereas, according to the data given earlier in the paper, an increase in the acidity or alkalinity of the milling agent causes *increased* swelling and is accompanied by an *increased* rate of shrinkage. Such a contradiction is important in proving that *swelling itself does not determine the milling properties of a wool*, although under particular conditions it may be directly related to that factor which is immediately involved.

The validity of the preceding deduction is based ultimately on the reliability of Harrison's experiments, and it is unfortunate that he should have failed to publish a record of his procedure and results. For this reason, a repetition of his study of milling as a function of temperature was undertaken. A Southdown worsted fabric, 74 in. wide, was split to single width and cut into lengths of 25 yards, each weighing 15½ lb. Midway along the length of each piece, an area one yard square was marked out in coloured cotton for the purpose of determining the extent of shrinkage after different times of milling. Before milling, each piece of cloth was wetted out in a scouring machine and then centrifuged to remove excess water. The cloth was afterwards fed into a small milling machine and the ends sewn up. At this stage the interior of the machine was raised to the desired temperature by means of a steam-heated coil, and when milling was commenced, 2½ pints of a stock solution of potash soap, warmed to the same temperature, were added gradually to the cloth. Throughout the whole series of experiments, the weight on the lid of the spout of the milling machine was kept constant, and the vertical rollers, which control the compression of the cloth web-ways, were kept at the same distance apart. At the end of each period of 30 minutes' milling, the machine was stopped and the area of the marked square determined. During an experiment, the temperature within the machine was kept constant by hand-adjustment of the steam-operated coil. The temperature of the cloth itself

was, of course, higher than that of the machine, and was determined three times during each period of 30 minutes by stopping the machine momentarily and inserting a thermometer into the folds of the cloth near the point where it emerged from the spout. It was found that a constant temperature difference existed between the temperature of the machine and that of the cloth. The temperatures given in Table XII, which summarises the results, are those of the cloth and not of the machine.

Table XII

Time (minutes)	Percentage Shrinkage in Area at			
	37.1°	42.0°	47.6°	52.4° C.
30	15.2	18.6	16.7	15.2
60	41.2	44.2	42.0	33.8
90	51.2	54.2	53.3	49.4
120	56.9	59.3	59.4	56.5
150	60.1	—	61.5	60.6

From the graph, Fig. 8, it is evident that shrinkage takes place most rapidly at about 45° C., in good agreement with Harrison's determination.

The preceding experiments thus afford a complete proof of the fact that swelling itself plays no direct part in determining the milling properties of a wool under any set of conditions. Should the truth of this deduction require further confirmation, it is afforded by the following experiments. At any given pH , the swelling of proteins in hydrochloric acid solution is reduced by the addition of sodium chloride. Use can be made of this property to study the rate of shrinkage of fabrics in media of the same pH , but in presence and absence of salt, *i.e.* in presence and absence of osmotic swelling. 5½ yards of a Cheviot cloth, weighing 3½ lb., was immersed in 10 litres of water to which 120 c.c. of concentrated (pure) hydrochloric acid were added. After 24 hours, the cloth was removed, centrifuged, and then milled in the fulling stocks. The milling agent was the acid solution with which the wool had attained equilibrium. A shrinkage-time curve was obtained as before by measuring the area of a marked rectangle at hourly intervals. In the second experiment the cloth was soaked in a solution consisting of 120 grams of sodium chloride, 120 c.c. of pure concentrated hydrochloric acid and 10 litres of water, the procedure being otherwise as before. Unfortunately, from the point of view of comparison of the results, more acid is adsorbed by wool in presence of salt, so that the final pH of the milling agent was higher in the second experiment—2.06 instead of 1.88. For this reason a third experiment was carried out, in which the cloth was soaked in a solution consisting of 150 c.c. pure, concentrated hydrochloric acid, 120 g. salt and 10 litres of water. In this case the pH of the milling agent was 1.74. From the three experiments it is possible to compare the rates of shrinkage of the same cloth at the same pH in presence and absence of salt; and to compare the rates of shrinkage for the same amount of acid used, in presence and absence of salt. Although salt has the property of depressing swelling, its presence increases the rate of shrinkage, as shown by the data of Table XIII.

Table XIII

Milling Agent	pH		Percentage Shrinkage in Area in					
			1	2	3	4	5 hours	
HCl	...	1.88	...	3.2	5.9	8.0	11.2	13.5
HCl + NaCl	...	2.06	...	3.3	6.5	9.8	13.3	17.0
HCl + NaCl	...	1.74	...	5.4	9.5	12.1	17.0	22.2

It must be emphasised, in connection with the preceding results, that the action of neutral salts cannot be interpreted without reference to the pH of the medium. Failure to observe this condition, especially in the case of sulphuric acid and sodium sulphate, has led to misleading conclusions with regard to the action of neutral salts in milling.

The Elastic Properties of Wool and their Relation to Milling Shrinkage

The part played by acids, alkalis and temperature in modifying the rate of milling shrinkage has been shown not to be due to changes in the swelling of the fibres. Some property of the wool fibre must be sought which changes in the same sense with increasing acidity, alkalinity and temperature. When identified, this property should be one which is directly concerned in determining the rate of shrinkage, and should be directly related to swelling in the case of acid and alkaline media. There is an inherent probability that the elastic properties of the wool fibre play an important part in milling, as foreshadowed by Harrison's and Shorter's views of the process, supplemented, more recently, by Arnold's theory of felting.⁸ Since the preceding theories were developed, it has been shown⁹ that acids and alkalis facilitate extension of the wool fibre to a remarkable degree. The results are summarised in Fig. 9, where the extent to which extension is facilitated by sulphuric acid,

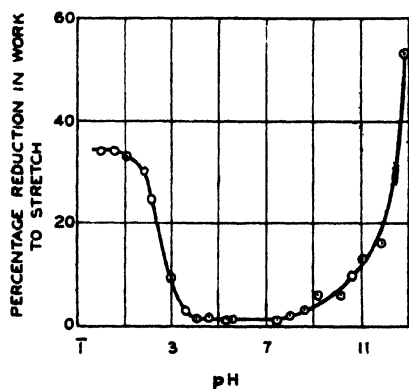


FIG. 9

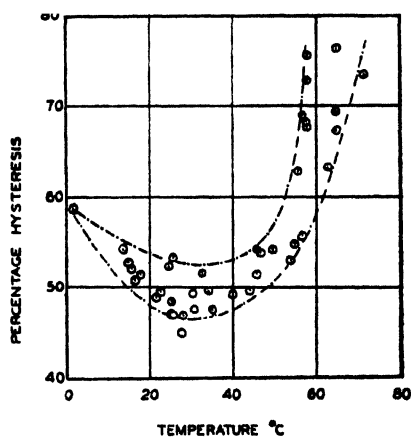


FIG. 10

sodium carbonate and caustic soda solutions is graphed against pH . There is a striking similarity between this curve and that of Fig. 1, where milling shrinkage is graphed against the pH of the milling agent. The rate of shrinkage is least in media between pH 4 and pH 8, the very region where fibres are most difficult to deform, explaining why agents such as Igepon A, which gives a pH of 6.5 in solution, are not recommended as milling agents. The parallel between the ease of extension and milling properties of wool fibres is maintained as regards the influence of temperature changes on both—in water, the ease of extension increases with rise of temperature, and so does the rate of milling, at least up to 45° C. Hence if extensibility, and not swelling, is assumed to be the important factor in milling, the contradiction between the action of acids and alkalis and of temperature disappears. To replace

swelling by extensibility is, however, not to resolve all the difficulties confronting the attempt to formulate a comprehensive theory of milling. Two contradictions still remain in the experimental data available. It has been shown (Fig. 1) that, beyond pH 10.0, milling shrinkage decreases with increasing alkalinity of the milling agent, whereas the ease of extension of wool fibres continues to increase. Similarly, the rate of shrinkage decreases with rise of temperature beyond $45^{\circ} C.$, whereas the ease of extension of wool fibres in water continues to increase up to $100^{\circ} C.$ Hence, although ease of extension of wool fibres may be essential for shrinkage to be possible, it is quite clearly not the sole determining factor.

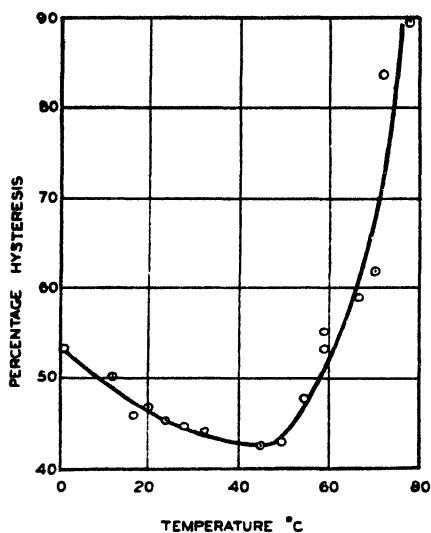


FIG. 11

Of particular interest in relation to the preceding difficulties is Arnold's theory of felting. Arnold has shown that during the felting process, fibres are stretched and migrate in much the same way as a worm crawls (*Regenwurmtheorie*). The same kind of action may occur in milling, and if Arnold's theory of felting is combined with Shorter's theory of milling, a closer interpretation of milling shrinkage becomes possible. Assuming, with Shorter, that each fibre in a cloth will have places of tight and loose entanglement, it is easy to imagine that, during milling, the entangled fibre will be stretched while piercing the loose entanglement. On release, the stretched fibre will attempt to return to its original length and, if the scales are directed correctly, will cling to the loose entanglement and draw it towards the place of tight entanglement. This mechanism of milling shrinkage is perhaps best visualised by regarding the fibre as an elastic sewing thread which draws up the fabric during its recovery from extension. Strong support for this view is derived from its ability to reconcile the two contradictions mentioned above.

According to the present theory, milling shrinkage is facilitated by ease of extension of the wool fibres but, for shrinkage to be possible, the stretched fibres must be capable of recovery from extension. Since wool fibres are known to take a permanent set in steam and boiling water, it thus becomes

possible that milling is most rapid at 45° C. because, although the ease of extension of wool fibres in water increases up to 100° C., the power of recovery may diminish. For this reason, a study was made of the hysteresis between extension and recovery of wool fibres in water at different temperatures. The apparatus used for this purpose was employed previously¹⁰ in determining the plasticity of wool, so that no new description need be given. Fibres were taken through a cycle of extension and contraction in water, extension being limited to 30%. There is considerable hysteresis between the two processes, as shown by the curves (Fig. 12) for a wool fibre in water

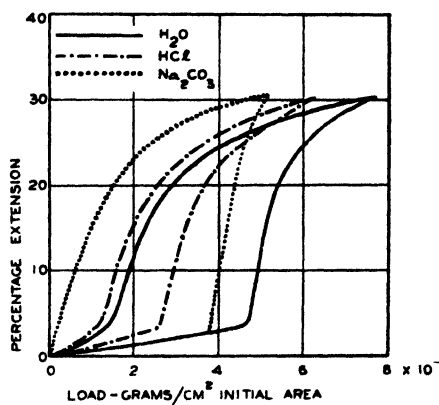


FIG. 12

at 25° C. The difficulty of recovery of stretched fibres is best measured by expressing the loss of work (the area of the hysteresis loop) as a fraction of the work required to stretch the fibre 30% of its length. This method of expression is particularly valuable in connection with milling, because ease of extension is necessary for rapid milling, and the difficulty of recovery from extension is most serious when it increases out of proportion to the ease of extension. Hysteresis data for Cotswold wool are given in Table XIV.

Table XIV

Temperature °C	Percentage Hysteresis		Temperature °C	Percentage Hysteresis
1.5	58.6	...	44.0	49.7
1.5	58.8		45.6	51.4
13.4	54.0		45.7	54.2
15.0	52.6		46.3	54.0
15.5	51.9		49.3	54.1
16.3	50.7		53.8	53.0
17.4	51.4		54.7	54.8
21.5	48.9		55.3	62.8
22.4	49.5		56.3	55.7
24.5	52.1		56.6	69.1
25.1	46.9		57.3	68.4
25.4	53.3		57.5	67.8
25.5	47.0		57.5	75.6
27.6	45.0		57.5	72.8
27.9	46.9		62.5	63.2
30.4	49.4		64.6	67.3
30.6	47.5		64.6	69.4
32.6	51.5		64.7	76.2
34.2	49.5		71.3	73.4
35.0	47.5		71.3	75.4
40.0	49.3			

Because of irregularities in the cross-sectional area of wool fibres, to which hysteresis measurements seem to be extremely sensitive, the experimental points lie within a zone as shown in Fig. 10. Despite the scattering of the points, it is evident that above 35° C. wool fibres show an increasing reluctance to recover from extension. The unsatisfactory character of the preceding data seemed to justify a repetition of the experiments with human hair, which is far more uniform in cross-sectional area. As shown in Fig. 11, the data confirm those for wool, except that the critical temperature is higher, 45° C. In view of these results, there can be little doubt that the existence of a critical temperature for milling at 45° C. is due to the fact that, beyond this temperature, an increasing ease of extension of wool fibres is overwhelmed by the decreasing power of recovery from extension.

Similarly, a study of the recovery of stretched fibres from extension in alkaline solutions leads to an explanation of the existence of a critical alkalinity for milling at pH 10.0; and a comparison of the recovery of fibres from extension in acid and alkaline media indicates why acid milling should be more rapid than alkali milling. Three fibres of human hair were allowed to attain equilibrium at 25° C. with water at pH 5.5, hydrochloric acid at pH 1.06, and sodium carbonate solution at pH 10.7 respectively. Each fibre was then taken through a cycle of extension and contraction in the medium with which it had attained equilibrium, extension being limited to 30%. The several hysteresis loops are shown in Fig. 12. Comparison of the properties of fibres in acid and in water, shows that although acid facilitates fibre extension, it does not diminish the power of contraction to any marked extent. There can, therefore, be no doubt that acid must be superior to water as a milling agent, as is well known to be the case. In alkaline solution, on the other hand, even though fibre extension is not facilitated to the same degree as in acid, the power of recovery is much reduced. Thus soda at pH 10.7 must be inferior to acid at pH 1.06 as a milling agent, in agreement with the data given in Fig. 1. With increasing alkalinity above pH 8.0, milling must at first be facilitated by the increasing ease of extension of the fibres, but at some critical pH this factor will be counterbalanced by a decreasing power of recovery. Beyond this point the rate of milling will decrease with increasing pH , as has been shown to be the case.

Besides facilitating extension, acids and alkalis increase the flexibility and compressibility of wool fibres, and in view of the fact that the milling process is based on purely compressive forces, it may seem a little arbitrary to restrict attention to the effect of reagents on fibre extensibility. It is, however, only on the basis of extensibility and recovery from extension that any adequate explanation of the existence of a critical temperature and pH for milling can be derived. Although increased flexibility and compressibility may facilitate milling shrinkage, the determining factors appear to be extensibility and power of recovery. As a corollary to this deduction it is evident that plasticity in wool must oppose and not aid milling shrinkage. Plasticity in wool is most pronounced in alkaline solution, but when plasticity is well developed as, for example, in solutions above pH 10.0, the rate of shrinkage decreases. Similarly, in acid solution, plasticity is far less than in alkaline solution, but the rate of shrinkage is much more rapid in the former instance.

One further matter deserves special comment. From the data of Table IV it is apparent that soap is a more efficient milling agent than alkali at the same

pH. Since fibre travel, and the stretching and contraction of fibres, must be opposed by frictional resistance with neighbouring fibres in a cloth, it is obvious that a lubricant will facilitate shrinkage. In view of the chemical composition of soap and the fact that it is strongly adsorbed by wool, there can be little doubt that its superiority as a milling agent is due to its additional qualification as a lubricant. It need hardly be said that an oil is of no service as a milling agent because it has no action in facilitating fibre extension.

CONCLUSION

From the preceding discussion it is evident that for milling shrinkage to be possible a fibre must—

- (1) Possess a surface scale structure.
- (2) Be easily stretched and deformed.
- (3) Possess the power of recovery from extension.

According to this view, it is evident that existing methods of imparting an unshrinkable finish to wool are not necessarily the most efficient. Unshrinkability is normally attained by treating wool with chlorine or hypochlorous acid, which have the effect of rendering the scale structure inoperative.¹¹ The wearing properties of wool are thereby impaired, so that in practice no attempt is made to realise complete unshrinkability. Instead, a compromise is struck between unshrinkability and wear. It is, however, now evident that unshrinkability may be realised, either by increasing the resistance of wool fibres to extension, or by decreasing their power of recovery from extension, or both. Such a method would have the merit of leaving the scale structure of wool intact, and wearing properties should at least be undiminished.

The type of compound necessary to accomplish such changes in elastic properties can be deduced from recent developments in knowledge of the structure of the wool fibre^{12,9}. In the unstretched state the latter is composed of long peptide chains which are coiled into a series of pseudo hexagons. Extension is accomplished by uncoiling the chains against the resistance of linkages between adjacent chains. One such linkage is formed by combination of the terminal amino and carboxyl groups of arginine, lysine, or histidine and aspartic or glutamic acid, respectively. It is of the ammonium salt type, and when a wool fibre is stretched in water, extension has to be accomplished by uncoiling the peptide chains against the attraction of oppositely charged ions of the salt linkage. Acids and alkalis both facilitate extension of the fibre by forming salts with the basic and acid components, respectively, of the salt linkage, thereby eliminating the attraction between the ions. In order, therefore, that extension and recovery may be hindered, and shrinkage properties reduced, it is evident that the existing salt linkage must be made more resistant to acid and alkali, either by conversion into a peptide linkage or by stable combination of another type. Alternatively, wool might be treated with a reagent having the ability to form new linkages between the peptide chains, linkages which would oppose extension of the fibre by preventing or delaying the uncoiling process. Only one agent of this type appears to be known—Permal NF, which operates in the acid dyebath. Other agents which are used to minimise shrinkage function in a totally different manner. They act as buffers and bring the *pH* of a soap solution into or near the region, *pH* 4 to *pH* 8, where the rate of shrinkage is normally least. Actually, the existence of such a region of minimum shrinkage is determined

by the fact that the salt linkages between the peptide chains of wool are stable to acid and alkali over this range of pH , as discussed in another publication.⁹ Not only, therefore, is it now recognised that acids and alkalis promote milling shrinkage by their action in modifying the extensibility and elasticity of wool, but their whole function can be interpreted in terms of the properties of the salt linkages between adjacent peptide chains. So precise an interpretation of the mechanism of milling shrinkage is not without industrial significance.

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CORRIGENDUM

8—"SOME CASES OF MILDEW ON SILK-CELLULOSE ACETATE MATERIALS"

By F. V. DAVIS, B.Sc.

In the February issue of this *Journal* (Transactions Section) on page T86, line 8, and page T88, lines 39 and 42, for "silk-acetate silk" read "silk-cellulose acetate rayon."

THE JOURNAL OF THE TEXTILE INSTITUTE TRANSACTIONS

28—THE CHEMICAL ANALYSIS OF RAYONS II—THE MICRO-DETERMINATION OF METALS IN COMMERCIAL RAYON YARNS

By B. P. RIDGE Ph.D. F.I.C. MARY CORNER B.Sc. A.I.C.
and H. S. CLIFF B.Sc.

CONTENTS

- I—Introduction and Summary.
- II—Methods for the Determination of Copper.
 - (a) The Gravimetric Method.
 - (b) The Catalytic Method.
 - (c) The Colorimetric Method.
- III—The Determination of Iron.
- IV—The Determination of Zinc.
- V—The Ashing of the Samples.

I—INTRODUCTION AND SUMMARY

The accurate determination of very small amounts of any one metal in the presence of others and of a large quantity of organic matter presents numerous difficulties, and hence it should be of value to place on record a description of methods that have been found to give reliable results in the case presented by the analysis of rayons. The present paper is devoted exclusively to such experimental procedures; the majority of the values actually found have already been published.^{2,3}

Although most of the common metals, iron, copper, aluminium, zinc, calcium, sodium, etc., have been found in the ash of the commercial yarns, it is considered that from the technical point of view the most important of these are copper, iron, and zinc, and so far the investigation has been confined to them.

The total metal content of rayons seldom exceeds about 5 mg. per 100 grams of dry material, and is frequently less than 2 mg., and the quantitative recovery of such small amounts from the large and bulky samples of cellulosic material required for analysis necessitates ashing of the yarn before the determinations can be made. During this operation it is possible to lose both copper and zinc, but it is shown below that under the conditions here employed such loss is reduced to a minimum.

Three methods for the determination of copper are described: a gravimetric method, in which the copper is precipitated and weighed as thiocyanate, a catalytic method which depends on the effect of this metal in accelerating the reduction of ferric salts by sodium thiosulphate solution, and a colorimetric method depending on the brown colour developed by diethyldithiocarbamate. Reliable values may be obtained by all three but the catalytic method is by far the most rapid, and involves no troublesome separation of other metals from the test solution.

For iron a modified procedure due to Knop¹⁶, in which the metal, present in the ferrous state, is titrated with potassium dichromate solution, is very satisfactory, whilst although it was not used for rayons in the present work, that elaborated by Lyons²³ and recently described by Davidson⁸ for the colorimetric estimation of this metal in cotton and solutions of sodium hydroxide should also be suitable.

The greatest difficulties have been experienced with zinc, since although most of the numerous methods cited in the literature for its micro-determination prove satisfactory for solutions of pure zinc salts, when copper, iron, aluminium, silica, etc., are also present, as in a solution of the ash from rayons, they do not appear to give reproducible results. Reasons for the rejection of some of these methods are given below, and the procedure finally adopted, in which the precipitation is made by means of 8-hydroxyquinoline, is described in detail.

Finally, factors found to be of importance during the dry ashing operation are discussed.

II—THE DETERMINATION OF COPPER

(a) The Gravimetric Method

Résumé—Potassium thiocyanate is added to an acid solution of the ash saturated with sulphur dioxide, and the precipitated cuprous thiocyanate is washed, dried, and weighed.

Procedure—A hank of the rayon was cut through at one place, divided into three, and plaited into a "pig-tail"; in this way it was found possible to ash without difficulty 40-50 gm. of the material in a platinum dish of 8 cm. diameter in an electric muffle furnace (see Section V). The residue was dissolved in 2 c.c. of constant-boiling (about 20%) hydrochloric acid, evaporated to dryness on the water-bath, and again treated with 2 c.c. of the acid; the solution was filtered into a small beaker of about 8 c.c. capacity, and washings of the paper and dish with hot distilled water were added until the final volume was about 6 c.c. The solution was saturated with sulphur dioxide, warmed gently until bubbles of gas were evolved, and 1 c.c. of a 10% solution of potassium thiocyanate was added from a small thistle funnel, the stem of which was drawn out to give a fine capillary jet. (By fitting a cork carrying a piece of bent glass tubing into the mouth of the funnel and attaching a mouthpiece of rubber tubing, the thiocyanate could be blown out as slowly as desired). The precipitate was allowed to settle during one hour, filtered by inverse filtration through a No. 3G3/<7 fritted Jena glass filter⁵, washed with cold water until free from thiocyanate, as shown by the absence of a red coloration on addition of ferric chloride to the last washings, further washed with 20% alcohol, dried overnight at 105°-110° C. in an electric oven, and weighed together with the filter and beaker, on an assay balance. Table I shows that for amounts of copper from 1 to 2 mg., the results are reproducible to within ± 3 per cent.

Table I
Determinations of Copper by the Gravimetric Method

Experiment	...	1	2	3	4	5	6	7	8	9	10
Mg Cu taken	...	2.00	2.00	2.00	2.00	0.94	0.94	0.94	0.94	0.94	0.94
„ found	...	1.99	1.98	2.00	2.00	0.93	0.945	0.97	0.95	0.92	0.925

(b) The Catalytic Method

Résumé—This method has been used by Baines¹ for the determination of traces of copper in silver nitrate to be used for photographic purposes. It depends on the fact that the reduction of ferric iron by sodium thiosulphate, which proceeds only slowly under ordinary conditions, is accelerated by the presence of copper salts to an extent that increases with increasing amounts of copper present.

A solution of the ash is mixed with an acidified solution of ferric alum containing ammonium thiocyanate as indicator; sodium thiosulphate solution is then added and the time to disappearance of the red coloration is measured by a stop-watch. The copper content of the ash solution is found from a previously established curve.

Procedure—The following solutions were prepared—

- (1) 5 gm. of ferric ammonium alum and 25 c.c. of 2*N*-hydrochloric acid per litre of water.
- (2) 2% Ammonium thiocyanate.
- (3) 0.1*N*-Sodium thiosulphate.
- (4) A solution of pure recrystallised copper sulphate containing exactly 0.01 gm. of copper per litre.

Into tall beakers of about 500 c.c. capacity, half immersed in a thermostat at 20° C., 100 c.c. of the ferric alum solution and 1 c.c. of the thiocyanate indicator were measured. One beaker was reserved for a blank experiment in the absence of copper, and to the remainder various accurately measured volumes of the standard copper solution were added. Twenty-five c.c. of the thiosulphate solution were pipetted into test tubes fastened to a rotatable rod in such a way that by turning the latter the contents of the tubes could be poured simultaneously into the beakers below. (Alternatively, inverted Y-shaped mixing tubes may be used).³ The rod was then turned so that the various reactants were mixed and the time of mixing was noted by means of a stop-watch. The end-point for each mixture, marked by the disappearance of the red coloration, was timed with the same watch, and the ratios T_0/T_{cu} were found and plotted against the various amounts of copper present. In this way a curve was established from which the amount of copper present in an unknown solution could be determined under the same experimental conditions. In the analysis of rayon yarns, about 10 gm. of material, in pellet form, were ashed in a platinum dish, the ash was dissolved in hydrochloric acid, and the solution evaporated to dryness. The residue, again dissolved in hydrochloric acid, was transferred to a beaker containing the ferric alum solution as described above, or alternatively, if a preliminary experiment had shown the amount of copper present to exceed 0.1 mg., the ash solution was diluted to a known volume and an aliquot part taken.

The curve from which the results are estimated should be found separately by each worker, since a personal factor enters into the determination of the exact end-point, but provided this is done the results are reproducible for the same solutions by different workers. (See Table III and Fig. 1).

Values of T_0/T_{cu} found by two different workers, in order to establish the fundamental curves from which the copper content of unknown solutions could be read off directly, are given in Table II and plotted against the amount of copper present in Fig. 1. From the latter it is seen that over the range 0.02 to 0.15 mg. of copper (T_0/T_{cu})—1 is proportional to the amount of

copper, whilst above the upper value the curve becomes concave upwards. No difficulty was experienced, however, in choosing conditions that would enable suitable amounts of the metal to be determined, and when once the ashing of the yarn has been done the determination is very rapid. The accuracy with which unknown amounts of copper can be determined is shown by Table III. Here the amounts of metal present in the various solutions were added by a second person, so that they were unknown to the worker performing the experiments, and the agreement found is very good.

Table II
Determination of Copper by the Catalytic Method

Mg. of Copper present			Mg. of Copper present		
T_0/T_{Cu} Ratio			T_0/T_{Cu} Ratio		
mg.	Worker A	Worker B	mg.	Worker A	Worker B
0.01 ...	—	1.6 ...	0.11 ...	8.5 ...	7.6 ...
0.02 ...	2.5 ...	2.2 ...	0.12 ...	9.5 ...	8.1 ...
0.03 ...	—	2.6 ...	0.13 ...	10.9 ...	9.2 ...
0.04 ...	3.6 ...	3.2 ...	0.14 ...	11.0 ...	9.6 ...
0.05 ...	4.1 ...	4.0 ...	0.15 ...	12.0 ...	10.9 ...
0.06 ...	5.3 ...	4.6 ...	0.16 ...	—	10.5 ...
0.07 ...	6.1 ...	5.6 ...	0.17 ...	—	12.1 ...
0.08 ...	6.7 ...	5.9 ...	0.18 ...	14.7 ...	13.0 ...
0.09 ...	7.4 ...	6.9 ...	0.19 ...	—	14.3 ...
0.10 ...	7.9 ...	7.1 ...	0.20 ...	17.1 ...	14.5 ...

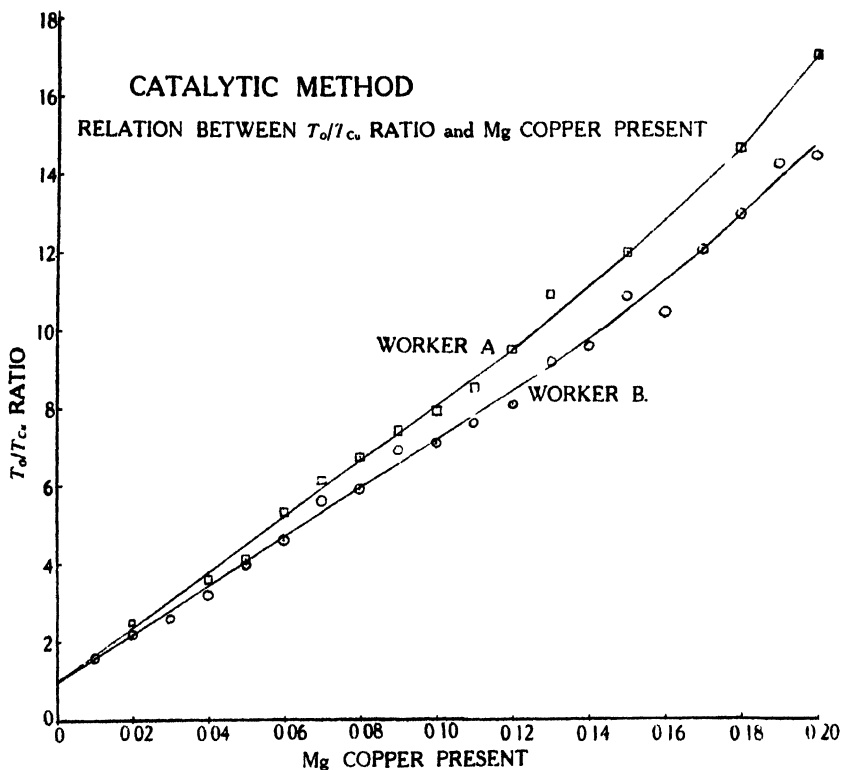


FIG. 1

Since there remained the possibility that the presence of metals, other than copper, might have a similar catalytic effect on the reaction, experiments were also made in which known amounts of lead, nickel, chromium and zinc

were present (a) with no added copper, and (b) with 0.1 mg. of copper. The results are recorded in Table V, which shows that in the absence of copper these metals have no such effect, nor do they interfere with the accurate determination of this metal. Since there is sometimes the possibility that platinum may also be present owing to attack of the dish in the ashing process (See Section V), the effect of adding this metal as platinum chloride and as platinum black was also studied. Table V shows, however, that amounts up to 10 mg. have no effect whatever in accelerating the reaction; hence evaporation of the ash solution to dryness, and ignition of the residue in order to remove this metal (and silica) before proceeding with the measurement of the time of reaction are not really necessary. The results obtained for the copper content of rayons by this method are given in Tables IV and VI, which also show their reproducibility for different samples of the same material.

Table III

Experiment	Time secs.	T_0/T_{Cu} Ratio	Copper Found mg.	Copper Present mg.
Worker A				
Blank	530	1	—	—
1	210	2.5	0.021	0.02
2	135	3.9	0.041	0.04
3	98	5.4	0.063	0.06
4	83	6.4	0.078	0.08
5	60	8.8	0.111	0.12
6	47	11.3	0.143	0.15
7	42	12.6	0.158	0.16
Worker B				
Blank	540	1	—	—
8	320	1.7	0.012	0.01
9	189	2.9	0.031	0.03
10	140	3.9	0.047	0.05
11	105	5.4	0.074	0.08

Table IV

Results on Rayons obtained by Workers A and B independently using the same Solution of Ash

(Mg. of copper per 100 gm. of dry material.)						
Variety	...	...	...	Cuprammonium	Acetate	Lilienfeld
Worker A	...	...	...	5.4	5.8	7.0
„ B	...	...	...	4.6	5.6	6.6

Table V

The Effect of the Presence of Metals other than Copper

Experiment	Time secs.	T_0/T_{Cu} Ratio	Copper Found mg.
Blank (no added metal)	530	1	—
„ +1 mg. lead	530	1	—
„ +1 mg. lead	535	1	—
„ +1 mg. nickel	540	1	—
„ +1 mg. nickel	545	1	—
„ +1 mg. chromium	525	1	—
„ +1 mg. zinc	525	1	—
0.1 mg. Cu +1 mg. Pb	63	8.4	0.105
„ „ +1 mg. Pb	60	8.7	0.109
„ „ +1 mg. Ni	63	8.4	0.105
„ „ +1 mg. Ni	60	8.7	0.109
„ „ +1 mg. Cr	67	7.9	0.100
„ „ +1 mg. Zn	67	7.9	0.100
Blank +1 mg. $PtCl_4$	530	1	—
„ +2 mg. $PtCl_4$	530	1	—
„ +5 mg. $PtCl_4$	540	1	—
„ +10 mg. $PtCl_4$	540	1	—
„ +Platinum Black	540	1	—

Since the application of this method to rayons in the present work a somewhat similar method has been elaborated by Brownsett, Farrow and Neale⁸, which depends on the fact that the reaction between sodium thio-sulphate and hydrogen peroxide is also accelerated by the presence of copper. The end point of the reaction is much sharper than in the method now described, but iron interferes and must be removed. According to Haddock and Evers¹⁵, when removal of iron from a solution containing both iron and copper is effected by means of ammonium hydroxide, some of the copper is also carried down, whilst separation of the copper as sulphide, as recommended by Elvehjem and Lindow¹⁰, is also unsatisfactory since some of this metal is retained by the iron. It is therefore desirable to avoid such separations if possible.

Table VI
Copper Content of Rayons by the Catalytic Method

Rayon used				Copper		Mg. Copper per				
Variety		Dry Weight		T_0/T_{Cu}	Found		Rayon		Mean	
		gm.			mg.		gm.			
VISCOS RAYONS										
Viscose IA	...	54.1	...	2.2	...	0.017	...	0.13	}	0.12
		49.9	...	4.6	...	0.053	...	0.11		
,, IB	...	8.53	...	2.1	...	0.016	...	0.19	}	0.19
		9.26	...	2.2	...	0.017	...	0.18		
,, IC	...	6.71	...	1.7	...	0.01	...	0.15	}	0.14
		6.77	...	1.6	...	0.009	...	0.13		
,, ID	...	8.23	...	1.5	...	0.007	...	0.08	}	0.11
		8.86	...	1.7	...	0.012	...	0.13		
,, IE	...	8.92	...	4.2	...	0.046	...	0.58	}	0.69
		7.88	...	5.3	...	0.062	...	0.79		
,, II	...	9.00	...	2.8	...	0.026	...	0.29	...	0.29
,, IIIA	...	9.00	...	1.4	...	0.006	...	0.07	..	0.07
,, IIIB	...	21.5	...	2.1	...	0.016	...	0.07	...	0.07
,, IVA	...	6.45	...	2.0	...	0.015	...	0.23	}	0.23
,, IVB	...	8.75	...	2.3	...	0.019	...	0.22		
CUPRAMMONIUM RAYONS										
Cuprammonium I ...		7.46	...	4.4	...	0.049	...	0.66	}	0.75
		8.15	...	6.8	...	0.083	...	1.02		
		8.19	...	5.3	...	0.061	...	0.75		
		11.22	...	5.7	...	0.067	...	0.60		
,, ,, IIA		4.72	...	12.2	...	0.152	...	8.05	}	8.06
		5.33	...	13.9	...	0.172	...	8.06		
,, ,, IIB		9.00	...	3.5	...	0.036	...	1.00	...	1.00
LILIENFELD RAYONS										
Lilienfeld I	...	8.23	...	1.6	...	0.009	...	0.11	}	0.11
		8.98	...	1.7	...	0.010	...	0.11		
,, II	...	8.86	...	15.6	...	0.188	...	5.30	...	5.30
ACETATE RAYONS										
Acetate I	...	5.10	...	11.3	...	0.143	...	7.00	}	7.00
		7.54	...	17.7	...	0.203	...	7.00		
,, II	...	10.25	...	9.8	...	0.124	...	3.03	}	3.03
		9.50	...	5.25	...	0.061	...	1.60		

(c) The Colorimetric Method

This depends on the fact that when a solution of sodium diethyldithiocarbamate is added to a solution of a copper salt made alkaline with ammonia, a brown coloration is obtained that varies in intensity according to the amount of metal present.⁴ The presence of iron, however, interferes with the determination of the copper, and in the present work the solution of the ash from about 10 gm. of rayon was treated with ammonia and the precipitated iron, etc. removed by filtration as recommended by Callan and Henderson.⁴ The filtrate and water washings of the precipitate were diluted to a suitable volume, an aliquot part was transferred to a Nessler tube, diluted with water, treated with ammonia and with a 1% solution of the reagent, and the colour of the liquid was matched in the usual way against those of suitably prepared standards. In view of more recent work, however, this procedure is open to objection. When no iron is present the results obtained by it are very good, as shown by Table VII where comparison is made between values found by this and by the catalytic method, but as stated previously, it has recently been shown by Haddock and Evers¹⁵, that if iron is removed by means of ammonia as above, some of the copper is also carried down, and low values are obtained. This is confirmed by the results recorded in Table VIII, which indicate that although no loss of copper is observed when iron is not removed, separation of the latter is accompanied by a loss of this metal, which may amount to 17% of the amount originally present, whilst copper can be detected in the ferric hydroxide precipitate. It is therefore recommended that the procedure of Haddock and Evers should be adopted, whereby citric acid is added to prevent the precipitation of iron by the ammonia, and the copper-diethyldithiocarbamate compound is removed by means of carbon tetrachloride before the colorimetric estimation is made.

Table VII

Determination of Copper in the Same Standard Solution by the Colorimetric and Catalytic Methods

Copper Present mg.	Copper Found, mg.					
	Catalytic Method		Colorimetric Method			
	Assistant B		Assistant A		Assistant B	
0.010	...	0.011	...	0.011	...	0.0115
0.030	...	0.031	...	0.032	...	0.0295
0.050	...	0.047	...	0.050	...	0.049
0.070	...	—	...	0.070	...	0.068
0.090	...	—	...	0.090	...	0.090

Table VIII

Effect on the Copper Content of Removal of Iron by Ammonia

Copper Present				Copper Found		% Copper lost
				Iron Not Removed	Iron Removed	
0.5 mg.	...	...	...	0.50 mg.	0.412 mg.	...
				0.50 "	0.412 "	
0.05 "	...	...	...	0.05 "	0.0445 "	...
				0.05 "	0.0445 "	

It is probable that, apart from variations in the copper content of rayons which are known to occur from sample to sample, some of the lower results shown in Table I of the paper by Ridge Parsons and Corner²⁰, which were obtained by the colorimetric method described above, are due to loss of the metal resulting from separation of the iron as ferric hydroxide.

III—THE DETERMINATION OF IRON

Résumé—The method employed was essentially that described by Knop¹⁰, in which the metal present in the ferrous state was titrated with potassium dichromate solution, a solution of diphenylamine in concentrated sulphuric acid being used as indicator. Some difficulty was experienced in finding a suitable reagent for reducing the iron to the ferrous state; stannous chloride and phosphoric acid, recommended by Knop, were both found to contain iron, and various other reducing agents were found unsuitable for the same or other reasons, but finally the addition of pure magnesium ribbon to the acid liquid enabled the reduction to be satisfactorily performed.

Procedure—The iron was determined in the filtrate and washings remaining after removal of copper as thiocyanate. The liquid was evaporated to dryness in a glass boiling-tube, the residue dissolved in aqua-regia, the solution evaporated to dryness, the residue redissolved in 1 c.c. of constant-boiling hydrochloric acid, and diluted with a few c.c. of water. About 0.2 gm. of pure magnesium ribbon, broken up into small pieces, was added to the liquid, and the reaction was allowed to proceed until a drop of the solution showed only a faint pink coloration with potassium thiocyanate solution. The contents of the tube were filtered if necessary and then transferred quantitatively to the bulb of a micro-titration apparatus¹⁰, 2 c.c. of constant-boiling hydrochloric acid and 3 drops of a 1% solution of diphenylamine in concentrated sulphuric acid were added, and 0.02*N*-potassium dichromate solution was run in from the burette until a permanent blue coloration was obtained. Blank experiments on the reagents used showed absence of iron, and the amount of this metal present in the rayon was obtained from the dichromate titre in the usual way.

The results found for rayons are given in Table I of the paper referred to above, while others illustrating the accuracy of the method are recorded in Table IX.

Table IX
Determination of Iron in Standard Solutions

Experiment No.	...	...	...	1	...	2	...	3
Iron found, mg. ...	...	...	...	1.524	...	0.989	...	1.036
Iron present, mg. ...	...	...	...	1.506*	...	1.000**	...	1.000**

* No copper present.

** After removal of copper.

IV—THE DETERMINATION OF ZINC

Preliminary experiments indicated that the zinc content of rayons is very small, so that methods that fail to estimate 2 mg. or less could be neglected. As already stated, numerous methods are described in the literature, but errors of considerable magnitude were in general obtained by their use when any separation of metals such as copper and iron was involved. The following were among those examined, and were rejected for the reasons stated.

1—*A nephelometric method*¹¹, depending on the precipitation of zinc by potassium ferrocyanide and comparison of the cloud so formed with standards prepared under similar conditions. Good results were obtained with solutions of pure zinc sulphate, but when the removal of copper and iron was necessary, reproducible values could not be obtained.

2—*Determination as sulphate.*¹² Copper was removed by treatment of the acid solution with aluminium foil, and zinc was then precipitated as sulphide from the liquid buffered at $pH 2$. The removal of copper was sometimes incomplete, and variable results were obtained.

3—*The resorcinol method.*²² Difficulty was found in obtaining within a reasonable time the blue colour stated to be formed when an alcoholic or ethereal solution of resorcinol is added to an ammoniacal solution of zinc.

4—*The "Oxine" method.*¹³ This has been shown by Geake to be very satisfactory for amounts of the order of about 5 mg., but no precipitate was obtained by the procedure described with amounts of about 0.5 mg. even after allowing the solution to stand overnight. It is probable that some alteration of the conditions would enable such small quantities to be determined, but since the method actually adopted had been found satisfactory in this respect no attempt was made to adapt the above to new conditions.

5—*Determination using pyridine and potassium cyanate.*⁹ A precipitate was formed with amounts of about 1 mg. of zinc, but the values obtained were not reproducible.

6—*Precipitation of zinc by means of diammonium hydrogen phosphate*¹⁷ *with subsequent estimation of the phosphorus.*¹⁴ Large negative errors were found, probably due to the excessive solubility of the zinc ammonium phosphate in the wash water.

Unsuccessful attempts to develop micro-methods of analysis were also made with the aid of the following reagents: creatinine,¹⁸ acridine, strychnine sulphate, nicotine, and sodium carbonate. Precipitates were obtained with all of them, but with the first three the development was either too slow with about 1 mg. of zinc or was not quantitative. That with nicotine contained no nitrogen, so that no zinc-nicotine complex was formed, and the precipitate was most probably a basic sulphate. With sodium carbonate solution good results were obtained with zinc alone, but the values were unsatisfactory if removal of iron and copper was involved. Finally the following method, involving the use of 8-hydroxyquinoline was found satisfactory.

Résumé of the method adopted. (a) The copper in the ash solution is removed as sulphide, citric acid is added to the filtrate to prevent precipitation of the iron, the liquid buffered to $pH 2-3$ by means of a formic acid mixture, and zinc is precipitated as sulphide.¹²

(b) The zinc sulphide is dissolved in dilute acid, the liquid suitably buffered with acetic acid and sodium acetate, a solution of 8-hydroxyquinoline reagent in acetic acid is added and the precipitated zinc compound is washed, dried, and weighed.

The method of precipitation of the zinc as sulphide from a formic acid solution after removal of the copper, has the great advantage that interference by other metals such as iron, aluminium, etc., or by silica in the precipitation with 8-hydroxyquinoline is thereby avoided.

Procedure

The following solutions were used—

- (1) Citric acid, 200 gm. per litre.
- (2) Formic acid mixture—20 c.c. of formic acid, 3 c.c. of ammonia ($D 0.88$), 20 gm. of ammonium sulphate, diluted to 100 c.c.
- (3) Formic acid 100 per cent.

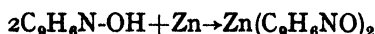
About 200 gm. of the rayon yarn was cut up, mixed thoroughly, and compressed into pellets. In each determination approximately 50 gm. of these were ashed in silica dishes in an electric muffle furnace at a temperature of 450-500° C. (See Section V), the residue was warmed with 1 c.c. of distilled hydrochloric acid (about 20%), the solution diluted slightly with water and filtered into a boiling tube. The dish and residue on the filter paper were washed with several small quantities of water, the filtrate was diluted to about 5 c.c., so that it was approximately 1*N* in hydrochloric acid, heated to boiling, and hydrogen sulphide was passed in for about 2 minutes until the copper was precipitated as sulphide, the supernatant liquid remaining clear. The whole was then filtered through a No. 44 Whatman paper into a suction filter tube, similar to that described by Clibbens and Geake⁶ and after the residue had been washed with very dilute hydrochloric acid, saturated with hydrogen sulphide, the liquid was concentrated on a steam bath to about 1 c.c., the evaporation being accelerated by blowing a current of air through the tube. To it was then added 0.25 c.c. of the citric acid solution, the mixture was neutralised (methyl orange) by the addition of ammonia, and 0.25 c.c. of the formic acid mixture and 0.2 c.c. of formic acid were added. The solution was warmed to about 40° C., hydrogen sulphide passed in, the liquid further heated to boiling, and, after removal of the burner, the side tube was closed and the vessel allowed to cool to room temperature while still connected to the hydrogen sulphide supply, the capillary tube being also closed before removal of the latter. The precipitate was allowed to settle, filtered off, washed with distilled water, dissolved in a small quantity of roughly 2*N* hydrochloric acid, and any residue in the filter tube was also dissolved and added to the main bulk. The excess hydrogen sulphide was then evaporated, the liquid made alkaline with ammonia, the excess ammonia removed on a steam bath, the solution diluted to about 70-80 c.c., and the zinc determined in the following way.

Solutions required—

- (1) 30% acetic acid.
- (2) A solution of 4 gm. of 8-hydroxyquinoline in 8 c.c. of glacial acetic acid, diluted to 100 c.c. This reagent is very stable and may be kept for months.

To the solution containing zinc, 2 c.c. of the acetic acid and 3 gm. of recrystallised sodium acetate were added, the mixture was heated to 40° C. on a steam bath, 5 c.c. of the hydroxyquinoline reagent were run in from a pipette, with stirring, and the whole was heated to 90° C. before allowing the precipitate to settle overnight. Finally, the latter was filtered through a fritted Jena glass filter (12G3), washed with hot water till the washings were free from sulphate and chloride, and dried at 150°-160° till of constant weight.

The reaction involved is represented thus—



so that 353.5 gm. of the compound are equivalent to 65.38 gm. of zinc, giving a factor for the metal of 0.1849.

The results given in Tables X-XII show the accuracy with which zinc may be determined (a) in pure zinc sulphate solution, (b) in the presence of added copper and iron, and (c) in the presence of copper, iron, aluminium

and magnesium. The values for the zinc content of some commercial rayon yarns are recorded in Table XIII.

Determination of Zinc

Table X

Experiment No.	A In Pure Zinc Sulphate Solution			B In Zinc Sulphate + 1 mg. Copper per 5 c.c. Solution				
	1	2	3	4	5	6	7	
Zinc found, mg.	0.978	0.980	0.965	...	0.958	0.998	0.940	0.976
„ present „	0.977	0.977	0.977	...	0.977	0.977	0.977	0.977
Difference ...	+0.001	+0.003	-0.012	...	-0.019	+0.021	-0.037	-0.001

Table XI

Experiment No.	A Zinc Solution + 1 mg. C pper + 1 mg. Iron per 5 c.c. Solution				B Zinc after Ashing with Filter Paper and Removal of Copper and Iron			
	1	2	3	4	5	6	7	8
Zinc found, mg.	2.011	2.015	1.024	1.021	...	1.989	0.950	1.014
„ present „	1.944	1.944	0.977	0.977	...	1.944	0.977	0.977
Difference ...	+0.067	+0.071	+0.047	+0.044	...	+0.045	-0.027	+0.037

Table XII

Experiment No.	Zinc in the Presence of Copper, Iron and Aluminium			Zinc in the Presence of Copper, Iron Aluminium, and Magnesium			
	1	2	3	4	5	6	7
Zinc found, mg.	1.316	1.160	...	1.220	1.305	0.977	0.943
„ present „	1.244	1.244	...	1.244	1.244	0.995	0.995
Difference ...	+0.072	+0.084	...	-0.024	+0.061	-0.018	-0.052

Table XIII

Zinc Content of Commercial Rayon Yarns

Variety	Yarn No.	Viscose					Acetate	Cupram- monium
		IB	IA	ID	IE	IIIA		
Zinc (mg. per	(1)	1.40	2.60	0.86	8.10	0.27	...	0.21
100 gm. of	(2)	1.36	2.61	0.25	7.82	0.21	...	0.37
dry rayon)	(3)	1.24	2.21	0.32	7.73	—	...	—
	(4)	—	—	—	7.95	0.13	...	—
Mean ...	...	1.33	2.47	0.48	7.90	0.20	...	0.29

V—THE ASHING OF THE SAMPLES

In some of the preliminary experiments in which the ashing of rayon was done in a platinum dish in an electric muffle furnace, considerable attack of the dish was observed, due possibly to the formation of carbide from the large excess of carbon present, and/or sulphide or disulphide, from the sulphur and alkaline ash constituents. This caused some of the metal to be dissolved during the subsequent treatment of the ash with acid, and on addition of the magnesium ribbon used in the determination of iron a black precipitate of platinum was obtained which masked, to some extent, the determination of the titrimetric end-point, although this trouble could easily be avoided by filtration of the liquid. No such attack was found, however, when an ordinary Bunsen burner was used for the ashing. According to Bertrand², a disadvantage of the use of a Bunsen burner in ashing is that in the presence

of carbon monoxide a volatile copper carbonyl is formed from the brass tube of the burner, which may be decomposed with deposition of copper on the vessel and material being heated; also, if copper is present in the substance being ashed, some of it may be lost if the conditions are such that carbon monoxide is formed, for the same reason. He has stated that if a current of carbon monoxide is passed over heated copper oxide in a glass tube, a deposit of metallic copper is obtained on the hot parts of the tube remote from the oxide, which he ascribes to the formation and subsequent decomposition of this copper carbonyl. In view of these facts it was considered advisable to study the effects of the ashing conditions more closely, and the following experiments were accordingly performed.

(a) *Attack of the Platinum Dish*—A weighed platinum dish was heated over a Bunsen flame for various times up to 2 hours, i.e. for periods longer than were required for the ordinary ashing experiments with rayons, but no change of weight was found, hence no transfer of copper from the burner to the dish or loss of platinum occurred. These results would be anticipated in view of the known behaviour under such conditions (pure platinum is not volatile at temperatures below $900^{\circ}\text{C}.$). To study the effect of carbon in the absence of mineral impurity, pure ash-free cane sugar was ashed both in the muffle and over the Bunsen flame, but again no change of weight was found, neither was the dish stained. When, however, the experiment was repeated after first moistening the sugar with a few c.c. of very dilute sodium carbonate solution, the dish was stained and a loss of 1.6 mg. of metal was found after dissolving away the alkaline residue. Sulphur alone, or mixed with sugar, caused no loss or staining, but a mixture of sulphur with sodium carbonate caused both. Other experiments were made in order to ascertain the approximate loss of platinum during the ashing of viscose rayon. A piece of platinum foil about 5 cm. square, weighing about 1.4 gm. was bent to form a shallow dish, and pellets of viscose rayon weighing 1.4 gm. were ashed in it (a) in the electric muffle at about $480^{\circ}\text{C}.$, (b) at about $680^{\circ}\text{C}.$, and (c) over the full flame of an ordinary Bunsen burner, when the temperature of the flame immediately below the dish was $900^{\circ}\text{C}.$, while inside it was about $600^{\circ}\text{C}.$ at the hottest part. The dish was weighed before each experiment and after removal of the ash by dissolution in hydrochloric acid, and the following losses were found—

		Electric Muffle		Bunsen Burner
Temperature	... $480^{\circ}\text{C}.$	about 680°C	680°C	600°C inside 900°C underneath
Time of Ashing	... 4 hours	about $\frac{1}{2}$ hour	about $\frac{1}{2}$ hour	about $\frac{1}{2}$ hour
Platinum lost	... nil	0.0106 gm.	0.0128 gm.	nil

Weight of dish, about 1.4 gm Area, 26.5 cm

Temperatures were measured by means of a thermocouple

The results show that unless the temperature is quite low, and therefore the time required is considerably prolonged, ashing in the muffle causes greater loss of platinum than does ashing over the Bunsen flame. When viscose was ashed in the muffle under the above conditions, although considerable staining occurred, it was found that if the residue was further heated for a few minutes over the Bunsen flame before treatment with acid, the stains disappeared, and no platinum was lost. The alkaline ash constituents of rayons are therefore the chief cause of attack of the dish, but

loss of platinum, which may be considerable when a muffle is used, may be prevented by heating the vessel and contents over the Bunsen flame before dissolving away the ash.

(b) *Loss of Copper*—On repetition of Bertrand's experiment in which carbon monoxide was passed over heated copper oxide in a glass tube, a metallic mirror of copper was obtained only in the immediate neighbourhood of the heated oxide, and this was probably due to the reduction of oxide dust to metal on the walls of the tube, but although no mirror was formed on the hot parts of the tube remote from the oxide, the presence of copper there could be demonstrated by the usual tests although the amount was small, and since precautions had been taken to prevent any mechanical transfer of oxide to this part, it may be concluded that some volatile copper compound is formed and decomposed again, as stated by Bertrand.

In the ashing of rayons or other materials in which copper is present with a large excess of organic matter, the production of carbon monoxide is not impossible, and may lead to loss of the copper to be determined. Low results may also be obtained, however, if, owing to the excess of carbon, the copper in the ash is reduced to the metal and then forms an alloy with the platinum, from which it can be recovered only with difficulty on treatment with acid.

An investigation of the quantitative recovery of copper, undertaken as a check on the results recorded in Table I of the paper by Ridge, Parsons and Corner²⁰, was conducted on the following lines—(a) Accurately measured volumes (1-4 c.c.) of a standard copper solution containing exactly 1 mg. of copper per c.c. were evaporated to dryness in a platinum dish, the residue was ignited as under the ashing conditions, and the copper determined gravimetrically; (b) similar volumes of the standard solution were added to samples of cotton, generally 10 gm., which were then ashed over the Bunsen burner or in the muffle, the residue was treated either with hydrochloric acid as described above, or first with concentrated nitric acid and then with hydrochloric acid after evaporation of the solution to dryness; (c) similar volumes of the copper solution were added to excess of pure cane sugar, or to small quantities of cotton (in order to soak up the liquid), which were then covered with sugar, the material was ashed and the copper determined after treatment of the residue with hydrochloric or with both nitric and hydrochloric acids. For (b) and (c), both the gravimetric and the catalytic methods were used. Finally, in some experiments, after removal of the dissolved ash, the platinum dish was again treated with hot acid and the extract was examined qualitatively in order to ascertain whether the first dissolution of the ash residue had removed all traces of copper.

The results obtained, corrected where necessary for blanks in the absence of added copper, are given in Tables I and XIV, and it is seen that the errors in determining copper in the standard solution are small; they do not exceed about 1% for 2 mg. and about $\pm 3\%$ for 1 mg. of metal (see Table I). In the ashing experiments with cotton, both as cloth and as unspun material, somewhat greater losses are found which, however, do not exceed 10% of the amount of copper recovered; hence it may be concluded that the results recorded for rayons in Table I of the earlier paper²⁰ are of this order of accuracy. The values given in Parts i and ii of Table XIV were obtained by ashing respectively over the Bunsen burner and in the muffle, whilst the method of dissolution of the residual copper with hydrochloric acid was

the same in both, and they suggest that the latter method of ashing may be superior to the former, although a larger number of experiments is necessary before this can be stated with certainty.

Part iii of Table XIV shows that the use of nitric acid as well as hydrochloric is unnecessary for quantities of copper of the order of 1 mg. When concentrated nitric acid is used for dissolving the ash, the residue obtained after evaporation of the solution to dryness should be ignited before being redissolved in hydrochloric acid, otherwise some interference is caused with both the gravimetric and catalytic methods of determination. Further, attack of the platinum dish is greater when nitric acid is used than when hydrochloric acid alone is employed, and since copper oxide is readily soluble in hot 20% hydrochloric acid, whilst bright, metallic copper is appreciably so, there is no reason why quantitative removal of copper should not be effected by means of this acid unless alloying with the platinum has occurred to a considerable extent, in which case the dish is badly stained.

Table XIV
Recovery of Copper after Ashing

(i) OVER BUNSEN BURNER											
In presence of	...	...	Cotton Cloth				...	Loose (Unspun) Cotton		
Mg. copper taken	4.00	4.00	4.00	...	3.90	3.90	0.975	0.975	0.975
" " found (grav.)	3.67	3.78	3.69	...	3.90	3.68	0.925	0.920	0.920
Loss calculated as % of copper											
found	9.0	5.8	8.4	...	—	6.0	5.4	6.5	6.5
Copper lost, mg.	0.33	0.22	0.31	...	—	0.22	0.05	0.06	0.06
(ii) IN THE MUFFLE											
In presence of	...	...	Cotton Cloth				...	Loose (Unspun) Cotton		
Mg. copper taken	...	...	4.00	4.00	...	4.00	4.00	0.975	0.975	0.975
" " found (grav.)	...	...	3.89	3.75	...	3.90	3.97	0.988	0.955	0.955
Loss calculated as % of copper											
found...	...	...	2.8	6.7	...	2.6	0.8	-	-	2.1
Copper lost, mg.	...	...	0.11	0.25	...	0.10	0.03	-	-	0.02
(iii) OVER BUNSEN—WITH LOOSE COTTON											
Ash dissolved in	...	...	...	HCl			...	HNO ₃ (Ignited) and HCl		
Mg. copper taken	...	...	0.975	0.975	...	0.975	2.00	4.00	4.00	4.00
Mg. Cu found (catalytic)	...	...	0.97	0.96	...	0.965	2.00	3.85	3.85	3.85
Loss calculated as % of copper											
found	...	...	0.6	1.6	...	1.0	3.9	3.9	3.9	3.9
Copper lost, mg.	...	...	0.005	0.015	...	0.01	0.15	0.15	0.15	0.15
(iv) IN THE MUFFLE WITH SUGAR											
Ash dissolved in	HCl			...	5 c.c. HNO ₃		...	10 c.c. HNO ₃	
Mg. copper taken	4.00	4.00	...	4.00	4.00	...	4.00	4.00	4.00
Mg. Cu found (grav.)	2.93	2.75	...	3.34	3.74	...	3.40	3.56	3.56
Loss calculated as % of copper											
found	36.6	40.8	...	19.8	6.9	...	17.95	12.4	12.4
Copper lost, mg.	1.07	1.25	...	0.66	0.26	...	0.61	0.44	0.44

The results given in Part iv, Table XIV for ashing in the presence of cane sugar, show that here the losses of copper may amount to as much as 40% of the amount recovered. When sugar is ashed it first melts, then swells up, and finally forms a hard cake of carbon which nearly fills the dish. These conditions are much more favourable for the production of carbon monoxide,

and also for reduction of the copper to metal during the heating than are those that obtain during the similar treatment of cotton or rayons. Viscose rayons and other types of regenerated cellulose burn very easily, whilst acetate rayons are somewhat similar to sugar, since they first melt, but the charred mass subsequently obtained has a more open structure than with sugar. Hence, whilst loss of copper can be regarded as very small for the former types of rayon, it may perhaps be greater than 10% for acetate yarns. With sugar the losses found when dissolution of the ash is effected by means of hydrochloric acid alone are approximately halved when both nitric and hydrochloric acids are used. This suggests that reduction to metallic copper and alloying with the platinum occur, and that the more drastic treatment with nitric acid is necessary in order to give more complete recovery.

On the other hand, however, in the last two experiments of Part iv, Table XIV, when the ash residue was treated twice with 5 c.c. of concentrated nitric acid and twice with hydrochloric acid with intermediate evaporation to dryness, further treatment of the dish with hot acid after removal of the ash solution, and examination of the liquid by the copper-zinc-mercury thiocyanate test gave no reaction for copper, and since this test is very sensitive it must be concluded that no copper remained in the dish. Hence the losses recorded may be due in part to the production of a volatile copper compound during the ashing.

It cannot, of course, be assumed that the experiments in which cotton and sugar were used are strictly comparable with those in which rayon yarns alone were ashed, but it may be safely inferred that the conditions affecting the quantitative recovery of copper in the former apply also to the latter; hence, provided the material ashed does not behave in a similar manner to sugar, there is no reason why the ordinary methods of ashing and dissolution of the residue should not give results that are accurate within fairly narrow limits.

In the determination of zinc, the ashing should not be done in a platinum dish, owing to the readiness with which zinc-platinum alloys are formed; in the present work silica dishes were used. It has been stated⁷ that quantitative recovery of zinc cannot be effected after ashing in the dry way owing to volatilisation of the metal during the heating. Thompson²¹ however, has recorded values showing the recovery from zinc salts alone and combined with organic matter after ashing at temperatures between 450° and 800° C. which show that although zinc salts alone may volatilise at temperatures as low as 450° C., when organic matter is present the whole of the zinc is recovered, and temperatures up to 650° C. may in some cases be used without loss. The results now shown in Tables X to XII, which were obtained after ashing at 450°-500° C., indicate that within this temperature range no loss is to be expected; these conditions of ashing were maintained in all the experiments with rayons.

The alternative to dry ashing is acid ashing, but this process is very unsatisfactory on account of the large amounts of strong acids required, the long time taken for complete combustion, the production of acid fumes, and the difficulty of removing quantitatively the small amount of residual ash solution from the comparatively large vessel required to contain the material. Further, the metal content of the acids may be considerable, thus necessitating unduly large blank corrections. For these reasons no experiments with rayons were made by this method, and in two cases where

cotton was ashed with 4 mg. of added copper unsatisfactory results were obtained, so that for the purpose of the present work further investigation on these lines was considerable undesirable.

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29—A NOTE ON THE INHERITANCE OF KEMP IN BLACKFACE SHEEP

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INTRODUCTION

The presence of kemp fibres in the wool of domesticated sheep is a matter of no little moment both to the breeder and to those concerned with the manufacture of woollen materials. To the breeder kemp is important since it adversely affects the price he obtains for his fleece, and to the manufacturer kemp is wholly objectionable in all but the coarsest fabrics, for no method of removing it is available except the laborious one of hand-picking. In most of the fine-woolled breeds, the occurrence of kemp fibres is comparatively rare; their occurrence is sufficiently frequent in some breeds, however, notably the Cheviot, to cause considerable wastage. In view of this, it was thought that investigations should be carried out to ascertain, if possible, the mode of its inheritance.

The breed of sheep chosen for these investigations was the Scottish Mountain Blackface. It was deemed advisable, in order to study the inheritance of kempiness, to use a breed in which the occurrence of kemp fibres was very marked, and where, therefore, the percentage is relatively easy to measure. Further, it seemed reasonable to assume that, within limits, the mode of inheritance in one breed would give some indication of what is to be expected in other breeds.

CHARACTERS OF KEMP IN BLACKFACES

The term "kemp" is applied to those fibres, occurring in the fleeces of modern domesticated sheep, which represent the outer coat fibres of primitive sheep, Roberts,¹ Duerden,² Barker.³ In the Scottish Mountain Blackface breed, the typical kemp fibre is short, compared with the other fibres in the fleece, varying from 1 in. to 3 in. in length; in rare cases the length may exceed this. The fibre is much coarser than the other fibres, is opaque and, owing to the presence of an air-filled medulla, has a dead white appearance. In almost every case the fibre shows a very marked wave in one plane only. The distal end of the fibre terminates in a very fine tip. The fibre is very brittle, tensile strength being very low.

Kemp fibres exhibit an annual growth, with a period of maximum growth from early spring to September or October. The fibres are then shed. This forms an important distinction between these and other types of fibres which exhibit continuous growth.

THE CONSTITUTION OF THE BLACKFACE FLEECE

The fleece of the Scottish Mountain Blackface breed of sheep is very long and has a somewhat coarse appearance. On closer examination it is found to be composed of three classes of fibres; fine wool, long hair, and kemp, as reported by Blyth⁴ and Lochner;⁵ Darling⁶ gave average percentage figures of wool 73.5; long hair 20.5; and kemp 6.0, each by count. The percentage of kemp present in fleeces of different Blackface sheep varies enormously. Many animals have been encountered with less than 1% by weight, and from this the percentage ranges up to 38.9% by weight.

TECHNIQUE

In an investigation of this nature, where large numbers of the fleeces of individual sheep have to be compared, it is extremely important to discover the minimum number of samples which may be removed from each in order to yield data which are comparable.

In a preliminary survey of Scottish Mountain Blackface sheep kept at this Institute, it was found that kemp was not evenly distributed over the body. There is a bilaterally symmetrical area on the dorsal aspect where the variability is extremely small. This area forms a strip along the back from about the level of the eighth thoracic vertebra to the root of the tail. It extends laterally for about one inch on either side, but becomes broader than this posteriorly over the croup. It was found that the amount of kemp growing on this area is maximal for any particular animal. This observation agrees with that of Roberts.⁷ In order, therefore, to obtain samples containing the maximum amount of kemp in any fleece, it is essential that they be removed from this area. Outside this strip along the mid-dorsal line, the variability of the kemp percentage is extremely high.

In these investigations it has been the standard practice to remove two samples from each sheep in the month of November, *i.e.* at the end of the kemp growth period. The samples were removed from an area of skin just superficial to the head of the last rib on each side. The area for sampling being fixed by a definite anatomical point ensures that all samples are removed from locations that are comparable. Further, each of the sampling areas is within the strip of maximal kemp distribution. It might be argued that it is not sufficient to obtain samples which show only the maximum amount of kemp in the fleece, but that samples should also be removed from other areas to give some indication of the degree of variability and type of distribution in each sheep. The view is held by the writer, however, that samples obtained from the mid-dorsal strip are sufficient to furnish a good indication of the kempiness of the whole fleece. Since these samples are removed from an area in the middle of the fleece, their relative kempiness or freedom from kemp affords a rapid measure of the "quality" of the fleece as regards kempiness. If the dorsal samples show a very small amount of kemp, and it is known that this is maximal, the fleece as a whole must be relatively kemp-free. If, on the other hand, the dorsal samples show a very large amount of kemp, it is reasonable to suppose (and, in fact, experience has shown it to be the case) that the whole of the rest of the fleece is also kempy. It does not appear to be of great practical importance to know the details of the distribution of the kemp over the rest of the body in such cases.

In the laboratory, the kemp fibres were removed from each sample by hand. The non-kemp and kemp fractions were then placed in wire-gauze containers and degreased in several changes of benzene at 40° C. After air-drying they were then scoured in $\frac{1}{8}$ % saponin solution at 56° C. and rinsed in distilled water at the same temperature, the last two operations being performed in a special apparatus to provide constant agitation. This apparatus and the technique have been described in a previous paper.⁸

The measure of kempiness used throughout these investigations was the percentage weight of kemp in the sample. Since this is a relative weight, and since it has been shown⁹ that kemp fibres have almost exactly the same rate of regain as wool and hair fibres, it was not considered desirable to

obtain the absolute dry weights of the fractions. After rinsing, therefore, the fractions (in their containers) were placed in an incubator oven, maintained at a temperature of 70° C., for 12 hours, and then left for 24 hours to condition to laboratory atmosphere. They were then weighed and the percentage weight of kemp was calculated, the figure for mean percentage weight of the two samples from each sheep being used subsequently. In all cases where the kemp percentage figures for the two samples differed by five or more, the samples were discarded and no use was made of the figures. This occurred in 10% of cases. It was considered that errors in sampling or in classifying the fibres were most likely to be responsible for these discrepancies.

The sheep which have formed the basis for these investigations fall into two classes—

1—The entire flock of a Perthshire breeder, which has been carefully recorded for the past ten years.

2—Stud rams in breeders' flocks in many districts in Scotland.

Samples were removed from the stud rams mainly with the object of obtaining samples from their progeny in subsequent years. Owing to the fact that in most flocks the system of flock recording is not such as to obviate the possibility of mistakes, this was found to be impracticable.

The Perthshire breeder's flock has thus contributed the bulk of the material. In this flock the lambs are marked immediately after birth by means of an aluminium ear ring, and carefully recorded against respective sires and dams in the flock-book. Owing to the presence of birth-coat fibres in the fleece it is useless to remove samples from sheep until they attain the age of at least 18 months. Many of the older rams which sired the present stock had died or had been sold before these investigations were commenced. Consequently, no measure of their kempiness could be obtained. In the course of the next two years it is hoped to collect much more complete data.

RESULTS

Ewes

To gain an indication of the degree of kempiness exhibited by the flock referred to above, reference is made to Fig. 1. In this the frequencies of kemp percentage results are given for 263 adult ewes. It will be noted that 67 of these (or 25.48%) had less than 4% of kemp. In the class 8% to 11.9%, the second highest class, there are 57 animals (or 21.67%). It was suggested by Darling,⁷ on an examination of 190 sheep, the great majority of which were specially selected, that the average kemp content of the Blackface sheep was about 6%. The mean figure for the ewes from this flock was found to be 9.6% of kemp, which is considerably higher than Darling's figure, chiefly because these ewes were from a commercial flock. At the same time a considerable amount of selection against kemp had been practised for some seven years before the observations were commenced. The results shown in Fig. 1 illustrate the bimodal type of distribution which exists in the flock.

Rams

It is, of course, impossible to give figures for rams in the above flock to compare with those for the ewes, since the number available is small. In Fig. 2, however, the kemp percentage figures for 62 stud rams are given. These rams were sampled through the courtesy of breeders in almost every

Blackface sheep district in Scotland. They were representative of the best class of stud rams, and it is reasonable to suppose that a certain amount of selection for non-kempiness had been practised in breeding them. In this respect, therefore, they are suitable for comparison with the ewes in the flock above.

It is interesting that 20 of these rams (or 32.26%) had kemp percentages of less than 4, while 13 (or 20.97%) had kemp percentages of from 4% to 7.9%. In this case it seems doubtful whether any significance can be attached to the fact that the distribution curve has a bimodal form since the total number is relatively small. The figures indicate, however, that in a representative group of carefully bred stud rams the percentage of kemp in the fleece tends to be low; (over 50% had a kemp percentage of less than 8).

In Figs. 3, 4 and 5 the results obtained by examining female progeny from three of the stud rams used are represented. The samples were taken when the progeny were adult, *i.e.* aged from 18 months to 5 years, and on account of the ordinary farming practice in which wether lambs are sold before they attain maturity, only females were available. From other work, however, there is no reason to believe that any marked sex dimorphism exists where kemp percentages are being considered, and consequently it is suggested that the sample of the progeny used is a truly representative sample, even though it includes only animals of the female sex. Fig. 3 gives the distribution of the kemp percentage figures from the progeny of ram A which possessed a fleece with less than 1% of kemp. Of his progeny 45 animals are included, most of these being born in three consecutive years. By comparison with the ewe-flock distribution table (Fig. 1), it will be noted that this ram's progeny show a distribution in which 21 individuals (or 46.67%) show the low value of less than 4% of kemp, while the class 8% to 11.9% only consists of 11.1% of the total. Only four individuals showed a kemp percentage higher than 16%.

Fig. 4 shows similarly the progeny values from ram B with a fleece containing 28.9% of kemp. In these, which number 20, eight showed a fleece with between 12% and 15.9% of kemp. The numbers are small but the kemp values show a fair frequency curve. The use of this particular ram can be seen at once to have been a retrograde step in that his progeny show a far higher degree of kempiness than the average for the flock.

The kemp percentage figures for the progeny, 19 in number, of ram C, which showed 18.35% of kemp in its fleece, are given in Fig. 5. The distribution is rather irregular, but it will be noted that the chief mode is located in the class below that of the previous ram's progeny. Since 8 sheep (or 42.11%) showed values for percentage of kemp between 8% and 11.9%, it seems reasonable to deduce that this ram imparted a kempy character to his progeny, though he did not produce offspring with as high values of kemp as ram B (kemp analysis 28.98%).

In Figs. 6, 7, and 8, the kemp percentage figures are given for the progeny of three rams, D, E, and F, which were disposed of before these investigations were commenced; therefore no figures for the amount of kemp in their fleeces were available. From the breeder's remarks, however, it seems reasonably certain that none was in the less than 4% class, since he was under the impression that their fleeces were more kempy than the average; experience has shown that, on examination, fleeces which contain less than 4% (of kemp)

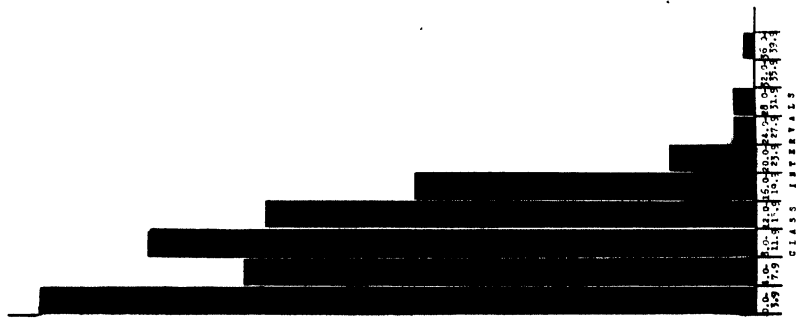


FIG 1—Distribution of the kemp percentages of a flock of 263 adult ewes

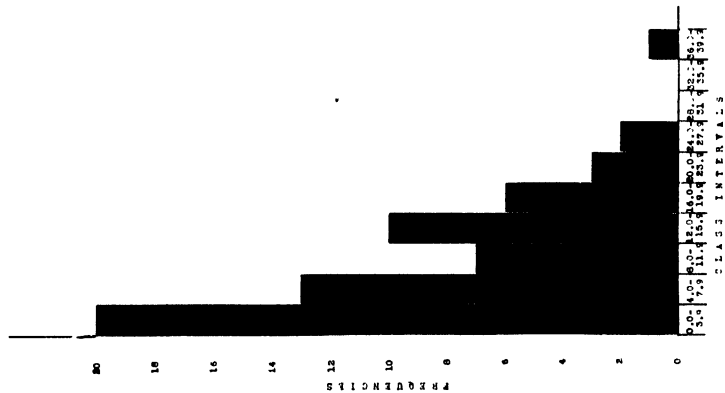


FIG 2—Distribution of the kemp percentages of a group of selected stud rams

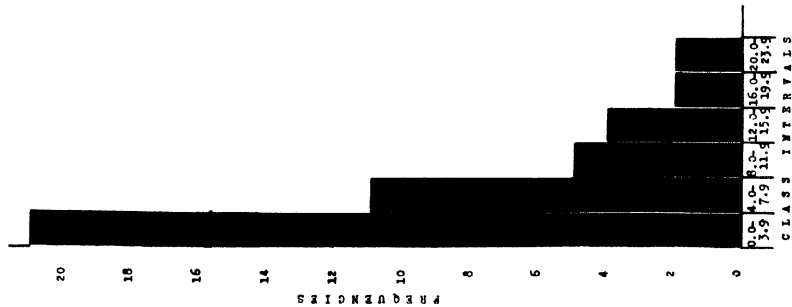


FIG 3—Distribution of the kemp percentages of the progeny of Ram A, which had a kemp analysis of less than 1 per cent

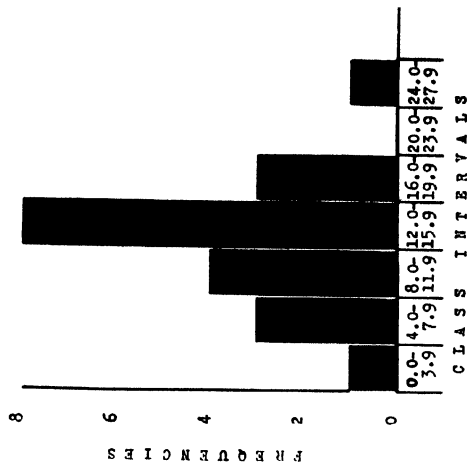


FIG 4—Distribution of the kemp percentages of the progeny of Ram B, which had a kemp analysis of 28.08 per cent.

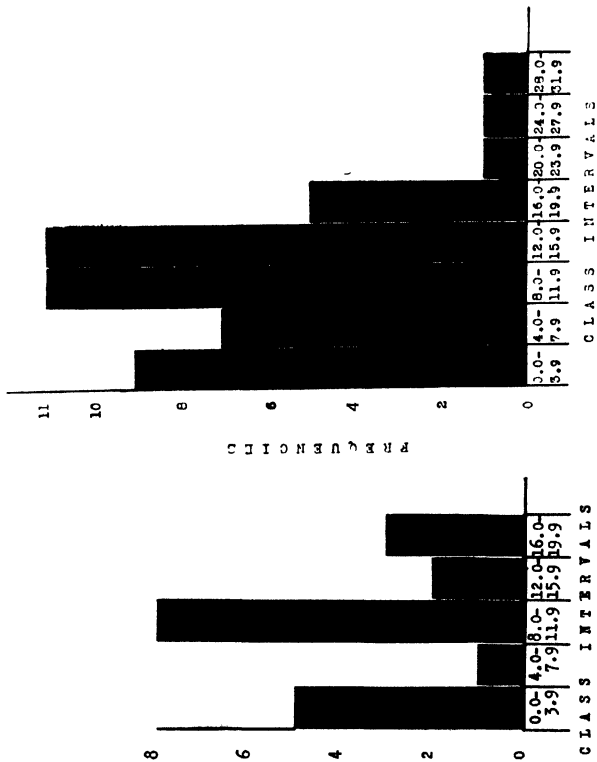


Fig. 5—Distribution of the percentages of the progeny of Ram C, which had a kemp analysis of 18.35 per cent

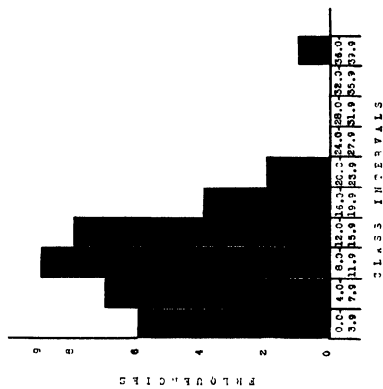


Fig. 6—Distribution of the percentages of the progeny of Ram D (not analysed).

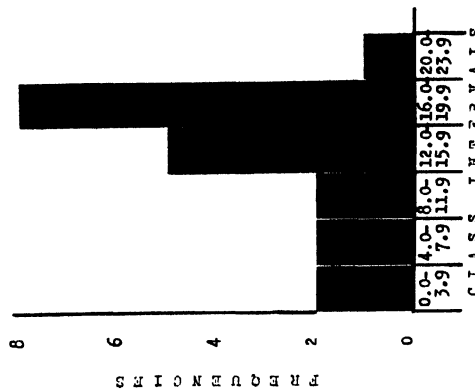


Fig. 7—Distribution of the percentages of the progeny of Ram E (not analysed).

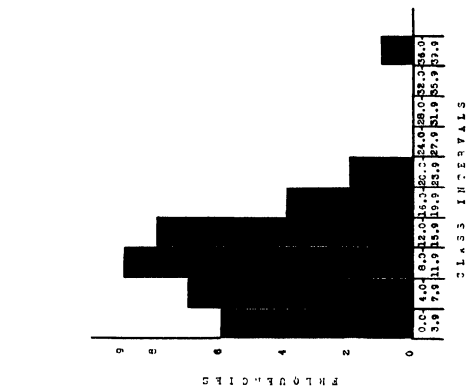


Fig. 8—Distribution of the percentages of the progeny of Ram F (not analysed).

appear very free from kemp. The progeny figures are shown because each group gives a frequency dispersion of considerable divergence from that of the ewe flock (Fig. 1). This supplies further evidence of the necessity for choosing stud rams with the greatest care, if it is desired to reduce the kempiness of the stock.

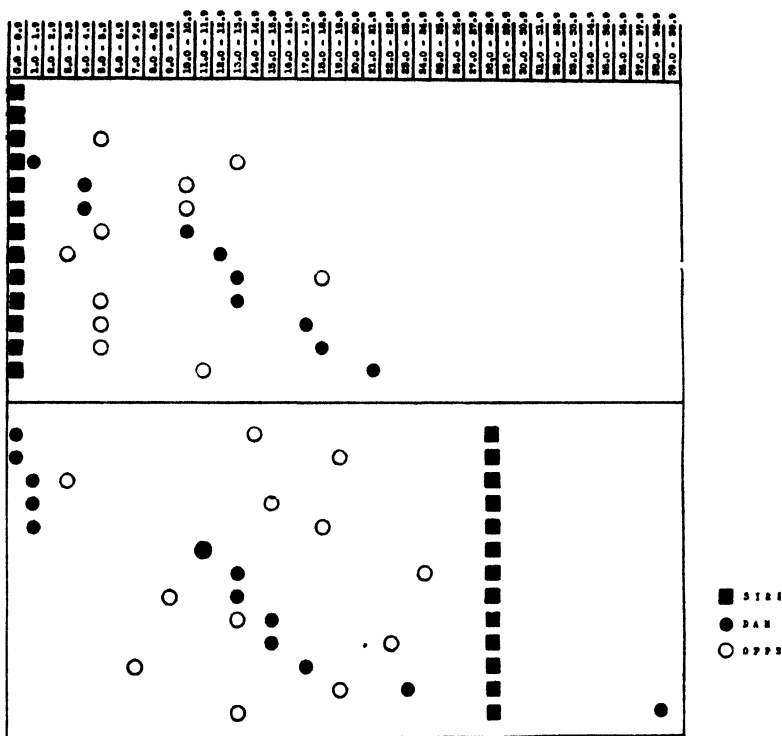


FIG. 9.—Diagram showing the kemp percentages of two rams, the ewes to which they were mated, and the resulting offspring.

(*) Sire, dam, and offspring were located in the same class.

(**) Sire and dam were located in the same class.

So far nothing has been said about the inheritance of kempiness through the dams. Unfortunately, owing to the practice of disposing of old ewes in September and October, very few of the dams of the existing stock have been available for sampling at the proper time, viz., the month of November. In Fig. 9, however, kemp percentage figures are given for the matings of two rams to 26 ewes and for the resulting progeny. One of the rams had a kemp analysis of less than 1%; the other ram had a kemp analysis of 28.98%. It will be noted that, of the progeny of the kemp-free ram eight out of 13 had less than 10% of kemp, even although their dams' kemp figures range up to 21.9%. Of the progeny of the kempy ram, only three out of 13 had kemp percentages of less than 10%, although their dams show a range up to 38.9% of kemp. These figures give at least some indication of the capacity of rams to impress a high or a low kemp percentage on their offspring.

DISCUSSION

Though the data may not be sufficient to warrant more than preliminary conclusions being drawn it is claimed that they are sufficiently important to be worthy of recording. A search of literature has failed to reveal any work hitherto published which gives results that indicate so clearly a hereditary basis for the occurrence of kemp in wool, nor can any be found in which any endeavour is made to suggest a mode of inheritance. Practical breeders have for many years past been aware in a general way that the *appearance* of kemp in wool, especially wool of the coarser variety, became more marked when sheep were put under methods of intensive feeding and management than previously. This led to the belief, still widely held by Blackface breeders, that forced feeding for show or sale purposes stimulated the growth of kemp, and was responsible for its production. This belief we know now to be only partly correct. There is a hereditary basis for the expression of kemp, which can be conditioned to some extent by the state of the metabolism of an individual. For example, the kemp fibre responds in thickness and rate of growth in length to altered conditions of feeding just as do the other wool fibres, but owing to its greater original thickness, and owing to its marked conspicuousness in the fleece, good nutritive conditions result in an apparently greater increase in the amount of kemp visible in the fleece on the living sheep.

It is not yet possible to state whether the proportions of kemp by weight in the sheep under good conditions is markedly different from what obtains in the same sheep under poor conditions of feeding, but we believe that the percentage content by weight will remain fairly constant.

If this view is found to be correct it will mean that it is of greater importance to manipulate the breed constitution than the environment of the sheep in an endeavour to reduce the amount of kemp in wool.

In the experiments, the results of which are given earlier, the sheep in the particular flock under consideration were kept under standard commercial conditions. The only variations to which they were subjected were such as refer to the seasonal differences in climatic conditions from year to year. These, obviously, cannot be controlled.

With regard to the variation in the percentage of kemp with the age of the animal, previous work showed that during the years of maturity, *i.e.* from the age of 18 months to five years, no appreciable variation in the percentage of kemp by weight in the fleece occurred, provided there was no gross variation in conditions, such as takes place, for example, when sheep are brought from high ground and confined in a pen under conditions of intensive feeding. In the case of aged animals (over five years of age) of both sexes, there is a decrease in the relative amounts of wool and long hair, with a consequent increase in the percentage weight of kemp. Such animals were not included in this investigation.

With further reference to the results obtained it should be noted that on theoretical grounds the degree of dispersion obtained from the progeny of any ram should have borne some resemblance to that obtained for the whole flock had genetic constitution played no part in determining the amount of kemp expressed. Such was not obtained. Ram A, whose fleece contained less than 1% of kemp gave progeny which show a distribution markedly better, if absence of kemp be the ideal condition aimed at, than the

distribution of the progeny of any other ram, and better than the flock as a whole. In the same way, the progeny from Rams B and F are worse.

It is worthy of note that of some 400 sheep of both sexes examined only one was encountered in which no kemp could be found. In a large number of the others, given as possessing "less than 1%," some few typical kemp fibres could still be found, although it is always easily possible to remove individual samples of wool, from shoulders or neck of sheep with low kemp content, which contain no such fibres. The fact that only one sheep, which could be regarded as kemp-free, was found, indicates that among commercial Blackface sheep it will probably be difficult, if not impossible, to eradicate this fibre from the fleece. It is desirable, therefore, to concentrate rather upon its reduction than its elimination. The survey shows that, disregarding all other characters of the wool, and paying no attention to body conformation, hardiness, colour, etc., it is possible to select for freedom from kemp, and given ruthless elimination of all sheep with high percentages of kemp in the fleece, it should be possible to produce and maintain a relatively kemp-free flock.

It is obvious that means to do this lie at first at any rate through selection of rams which possess a low kemp content. The upper portion of Fig. 9 shows that a ram (■) with less than 1% of kemp mated to a representative group of ewes (●) leaves progeny (○) which with three exceptions have less than 11% of kemp although six ewes showed more than this amount. Conversely, in the lower part of the same figure, the ram with 28% of kemp gave progeny only three of which showed less than 11 per cent.

It is legitimate to conclude from these results that kemp percentage by weight in the fleece is inherited intermediately; while there are indications that low kemp content may be dependent upon incompletely dominant factors transmitted by the sire. Owing to the difficulty of obtaining any considerable degree of homozygosity for degrees of kempiness in individual sheep, and because of the time it takes to build up such a homozygous flock, the exact mode of inheritance must be left for future investigation, but it may be mentioned that in all matings to date where both parents contained less than 1% of kemp, the progeny have produced fleeces with the same kemp value. Ram A (Fig. 3) left 48% of all his progeny with a kemp figure of less than 4%. It is suggested as a working hypothesis that by breeding from rams which possess less than 1% of kemp in their fleeces, marked improvements could be effected in the character of a clip provided elimination of animals with high amounts of kemp were practised simultaneously.

SUMMARY

1—A method of analysing kempiness on a weight percentage basis in Blackface wool by selecting samples from a definite anatomical area on the living sheep is described.

2—From a Blackface flock survey of the content of kemp in the fleece on a percentage by weight basis, it is possible to state that this forms a satisfactory method of assessing a value for the presence of kemp in the fleece.

3—Analysis of samples from parental and filial generations enables the following conclusions to be drawn—

- (i) Kempiness in the fleece is inherited;
- (ii) Rams with fleeces containing less than 1% of kemp leave greater numbers of progeny which approximate this figure than do more kempy rams;

- (iii) It should be readily possible to found and maintain a flock showing low kemp content provided such rams as show less than 1% of kemp were used and elimination of kempy sheep was carried out.

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THE JOURNAL OF THE TEXTILE INSTITUTE

TRANSACTIONS

30—THE KINEMATICS OF TWIST

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INTRODUCTION

Twist plays an important rôle in the manufacture of textile yarns, and its influence on the properties of the finished yarn is profound. It is, therefore, somewhat surprising that even the outlines of the theory governing the measurement and methods of producing twist should be so little known. The probable cause of this is that the idea of "twist" is usually considered so simple that it hardly needs defining; and yet, when an explanation of even the simpler methods of twisting a string is attempted, it is found that all sorts of anomalies arise unless the discussion is based on a very rigorous definition of what is meant by the twist in a string.

The intuitive idea of twist is based on the observations that the only way of twisting a straight string* is by rotating its ends relative to one another, and that in the ideal "worsted-type" of yarn the fibres on the surface lie in helices about the yarn axis. Unfortunately, a definition of twist having either of these facts as basis is only valid for the case of a string which remains straight, as can be shown very easily by simple experiments. For example, if the visual criterion of twist is taken, it can be made precise by saying that the string is twisted when lines on the surface which were originally parallel to the axis are deformed so that they make an angle with the axis, and the amount of twist is a function of this angle. That such a definition is of little use is evident when it is realised that even in the case of uniform twist, this angle varies from one generator (as we shall call the reference lines on the surface) to another, except in very special cases. Take, for example, the string shown in Fig. 1. This is a square sectioned rubber cord deformed so that its axis lies on a helix. It is clear that the centre line of the outer face is inclined to the axis, as is that of the inner face; but these two inclinations are not equal, and both are different from that of the centre line of either of the other faces. Which of these generators is to be used in estimating the twist? Even if in this simple case it is possible to answer this question, it is clear that there is no guiding principle which will apply to a string deformed in any other way. If, instead of being wrapped round the cylinder so that one face lies always in contact with it, the string has additional twist inserted, we are in a worse position still, since the angle between the axis and any generator varies from point to point along the generator.

* We shall use the term "string" to describe the object under investigation, whether yarn, cord, rope, wire, or other structure. It is assumed that the string is uniform in cross-section, and that in all deformations considered the original sections remain plane and perpendicular to the axis of the string.

That twist can be put into a string without relative rotation of the ends can be shown very simply. If the string is held in the form of a hanging loop, and one end is *translated* in a path completely encircling the other arm of the loop, the string becomes twisted, in spite of the fact that no change has taken place in the orientation of either of its ends. It is, in fact, possible to twist a string without any relative movement of the ends at all.

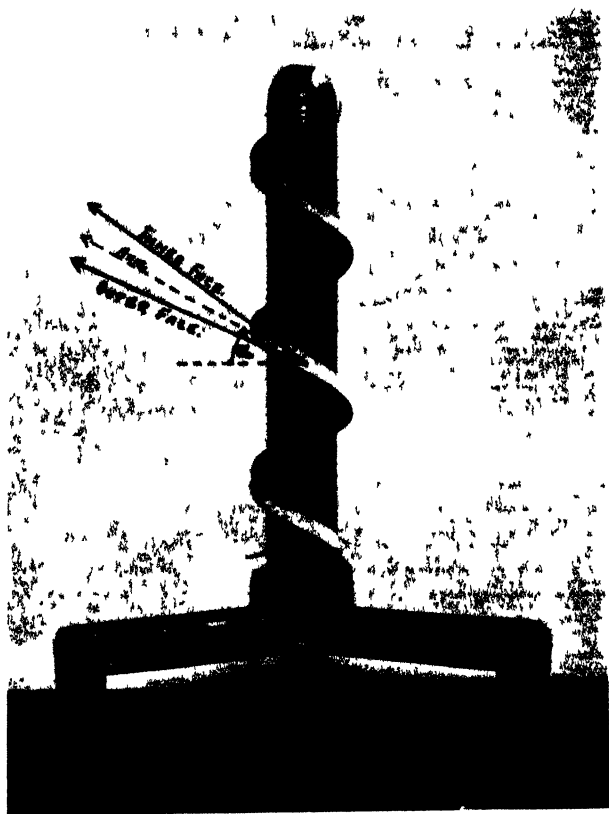


FIG. 1—A string deformed so that its axis lies on a helix. The angles between the axis and the centre lines of the outer and inner faces respectively are not equal.

These elementary considerations show that an adequate discussion of twist is impossible without stating precisely what the term "twist" is to imply. The definition adopted must apply to any string, whether straight or not, and must, in the former case, conform with those ideas which obviously apply to straight strings. It is the primary object of this paper to develop such a definition and to quote some simple consequences of it. The matter has been treated in some detail by Thomson and Tait¹, for a more rigorous treatment reference may be made to Love's standard text-book.² It is hardly necessary to point out that the matter of the following section is not original; our object here is to make accessible to textile workers a mathematical theory which is usually treated in works more familiar to the mathematician than to the technologist.

THE DEFINITION OF TWIST

We shall disregard for the purposes of this discussion, all questions relating to the material from which the string is made. Such a simplification is necessary in order that attention may be focussed on the subject proper. When quantitative results are derived, it must be realised that they are subject to this restriction, and may require modification before application to any special case.

The string which we consider is in the form of a cylinder of uniform circular cross-section when straight. We have already mentioned what is meant by a *generator* of the string; this is any line on the surface which is parallel to the axis when the string is straight and untwisted. The radii of any cross-section we shall call, with Thomson and Tait, the *transverses* in that section; there is a transverse in each section corresponding to each generator of the string. When the string is straight and untwisted the set of transverses belonging to any generator lie in a plane through the latter and the axis [see Fig. 2 (a)].

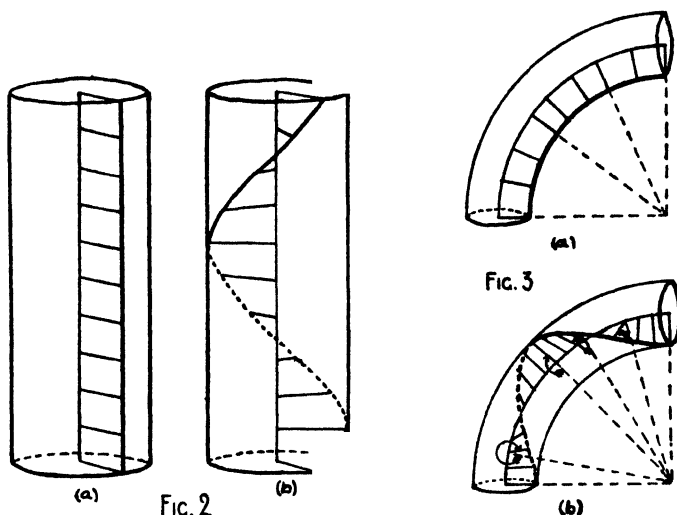


FIG. 2—Showing a generator and the corresponding transverses of a straight string (a) when untwisted and (b) when twisted.

FIG. 3—Showing the set of transverses to a chosen generator in a bent string (a) when untwisted and (b) when twisted.

The definition of the twist in the string, valid for all states of the string, can be stated forthwith. *The twist is defined as the rotation of the transverse to any chosen generator about the axis, per unit length of the axis**; that is to say that as we pass along the axis, the transverses rotate about the axis at a rate which is proportional to the twist in the string at the point considered.

In order to lead up to the general discussion of this definition, we shall take first the simpler cases of straight strings, and strings whose axes lie entirely in one plane.

* We shall always call right-handed twist "positive," so that positive twist is when the rotation is that of a right-handed screw, or clockwise as we look along the positive direction along the axis.

Straight strings—Fig. 2 (a) shows the string in its initial state, when the transverses to the chosen generator lie in a plane. When the string is twisted, the generator becomes a helix, and the transverses no longer lie in the same plane (Fig. 2 (b)). If that at a distance s from the origin makes an angle φ with a fixed plane through the axis, then the twist at that point is clearly, from our definition,

$$T = d\varphi/ds \quad \dots\dots\dots (1)$$

and the total twist in the string between $s=0$ and $s=l$ is

$$\Phi = \int_0^l T \cdot ds = \int_{\varphi_0}^{\varphi_l} d\varphi = \varphi_l - \varphi_0 \quad \dots\dots\dots (2)$$

that is, the total twist in any length of the string is equal to the angle between the transverses at its ends*. This result is obviously true for the transverses to *any* generator.

The "fibre-angle" method of measuring the twist is equivalent to the specification of the angle of the helix formed by a generator. The twist is then given as a function of this angle and the radius of the helix. This is to a certain extent inferior to the method given here, inasmuch as it makes use of the diameter of the string, whereas (1) and (2) do not.

Bent strings—In the case of a string whose axis, while not straight, nevertheless lies in a plane, matters are complicated on account of the change of direction of the axis from point to point. Let us take a simple case, such as that of the string shown in Fig. 3, where the axis of the string forms a quarter circle. We are at liberty to choose any generator of the string as reference line, so we take the one which lies in the plane of the axis and nearer to the centre of the circle. The transverses to this generator all lie in the same plane, as shown in Fig. 3 (a). If any other generator had been chosen, it is clear that the transverses would all make the same angle with the axial plane; this is, then, the criterion for zero twist in a bent string. Note that even when the string is untwisted the transverses are not necessarily parallel to one another.

When the string is twisted, as in Fig. 3 (b) the transverses are displaced from their original positions, and no longer make the same angle with the axial plane. By definition, the twist at any point is given by the change of this angle per unit length; in other words, it is given by (1), with the qualification that φ is now the angular displacement from the axial plane. We are no longer free to choose the plane from which the directions of the transverses will be measured; it is fixed for us by the shape of the string. The measure of the twist given by (1) is quite independent of the generator chosen, since in the untwisted string φ is constant for each generator.

Strings in general—The case which we have now to consider is when the axis of the string does not lie in the form of a plane curve; such, for instance, as the string in Fig. 1. The peculiar difficulty presented by this case lies in the fact that there is now no natural fixed plane to which we can refer the directions of the transverses. Yet in order to interpret our definition we must, in some way, be able to calculate the rate of rotation of the transverses about the axis; in the foregoing instances this was simplified by the fact that the axis was confined to a single plane, but this is not so in the present case. The following discussion shows how this difficulty is overcome.

* This angle, of course, may be greater than 360° . Unless otherwise stated, we shall measure angles in radians, and therefore twist in radians per unit length.

We notice first that although no one plane contains the whole of a "tortuous"* curve, as we shall call such curves in three dimensions, yet at each point it is possible to take a plane containing a short length of the curve. This plane is called the "osculating" plane at the point considered. Fig. 4

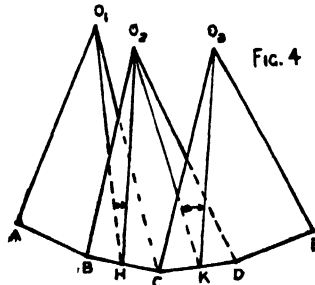


FIG. 4—The osculating planes at consecutive points of a tortuous curve.

shows how, in passing along the curve, the osculating plane changes from one point to another. A, B, C, D, and E are consecutive points on the curve; if we imagine that A, B, and C lie in the plane of the paper, then D and E do not—we may suppose, for instance, that they are above the plane; similarly A and E do not lie in the plane through B, C, and D, and so on. O_1H and O_2H are the perpendicular bisectors of BC in the planes ABC and BCD respectively; and O_2K and O_1K those of CD in the planes BCD and CDE respectively. The plane O_1ABC is the osculating plane at B—it contains B and the two neighbouring points A and C, but not D. So O_2BCD is the osculating plane at C, and O_3CDE that at D. The osculating plane at any point contains, besides that point, the next one on each side, but not, in general, any other nearby point. Since D does not lie in O_1ABC , the osculating plane at B, and since it does lie in the plane O_2BCD , these two planes must be inclined to one another at a small angle. Both planes pass through BC, however; consequently, in order to make them coincide, the plane O_1ABC must be rotated through a small angle about BC. Thus, in passing from a point B on the curve to the next point C, the osculating plane rotates about BC, which is the direction of the tangent at B. This rotation is indicated by the arrows in Fig. 4. It is evident that the faster the osculating plane rotates as we pass along the curve, the more the curve departs from planeness; the amount of the rotation (per unit length) we shall call the tortuosity* of the curve, and we shall denote it by τ . Thus in Fig. 4, if the length of BC is ds , the angle O_1HO_2 between the planes O_1ABC and O_2BCD is $\tau \cdot ds$, τ being the tortuosity of the curve at B. Now suppose that the curve AB.....E is part of the axis of the string, and suppose that we know the angle between the transverse at every point of the axis and the corresponding osculating plane. Let this angle be ϕ at B, so that the transverse at B makes an angle ϕ with the plane O_1ABC ; and at C let the angle be $\phi + d\phi$, so that the transverse at C makes an angle $\phi + d\phi$ with the plane O_2BCD . Since the latter plane makes an angle $\tau \cdot ds$ with O_1ABC , it follows that the angle between the transverse at C and the plane O_1ABC is $\phi + d\phi + \tau ds$. But the twist in BC is given by the difference between the inclinations of the transverses at B and C to the plane O_1ABC , and is therefore $d\phi + \tau ds$. The twist per unit length is obtained by dividing this by ds ; which gives us the result that the twist in any string is

$$T = \tau + d\phi/ds, \dots\dots\dots(3)$$

* The terms "tortuous" and "tortuosity" instead of "twisted" and "torsion" are used here for obvious reasons. The latter are, of course, the more usual.

τ being the tortuosity of the axial curve at the point considered. (Methods of computing τ cannot be discussed here; for the helix, which is the only tortuous curve for which we shall attempt to derive quantitative results, the

tortuosity is $\frac{1}{r} \cdot \sin \alpha \cos \alpha$, r and α being the radius and inclination of the helix; the latter term here, as always in this paper, refers to the angle between the tangent and a plane perpendicular to the axis of the helix.)

The occurrence of the tortuosity in the expression for the twist means that the string can be twisted simply by altering the shape of the axial curve, and that any such change may be expected to alter the twist in the string. Rotation of the ends of the string relative to one another changes the values of $d\varphi/ds$, and this to an extent depending on the amount of the rotation, *so long as the shape of the string is unaltered. If this condition is not fulfilled, then the change in the twist is not necessarily proportional to the relative rotation of the ends*, but depends also on the change in the shape of the axial curve.

As an example of this, the case of the string shown in Fig. 1 may be considered. In order to deform the string from the initial straight, untwisted state to the configuration shown, one end was fastened to the bobbin, which was then rotated about its axis so as to wrap the string round it, the free end of the string being held fixed. Each turn of the helix so formed necessitated a rotation of one end of the string through 360° , *but the rotation was about the axis of the bobbin, and not about the axis of the string*, since the latter no longer remained straight. For this reason the change of twist is not equal to the amount of the rotation. In (3), we know the value of τ , the tortuosity of the axial helix, so that the twist is known when we have determined the value of $d\varphi/ds$. In this case, it is easily seen to be zero, since a glance at Fig. 1 shows that the transverses to the centre lines of the outer or inner faces all lie in the osculating planes of the axis; therefore φ , and so $d\varphi/ds$ is zero at each point. Consequently the twist in the string is, from (3),

$$T = \tau = -\frac{1}{r} \cdot \sin \alpha \cos \alpha \text{ radians per unit length, } \dots\dots\dots(4)$$

the negative sign denoting left-handed twist. This is equivalent to $-2\pi \sin \alpha$ radians per turn of the helix. Deformation by this method into a flat helix (α small) gives little change of twist; when the helix is steep, the change of twist approaches 2π radians (or one turn) per turn of the helix, which value it attains when $\alpha=90^\circ$ (straight string, one end rotated through 360° about the axis of the string).

If we consider the operation of wrapping an initially twisted string round the bobbin by this method (i.e. by rotation of the bobbin, with the free end of the string held fixed) it is clear that the change of twist is again given by (4). This is an example of an important principle, which might be taken to be almost obvious, but on which it is well worth while laying some emphasis. —*The change of twist due to any deformation of the string is characteristic of that deformation, and is independent of the initial twist in the string.* In order to see that this is so, it is only necessary to consider that what we have called a generator of the untwisted string is a purely geometrical abstraction; in Fig. 2 (b), the string is twisted with reference to the generator shown there, but may also be regarded as untwisted with reference to another line drawn on the surface of the string parallel to the axis. The concept of

§ The tortuosity is positive in a right-handed helix, and negative in a left-handed one, such as that shown in Fig. 1.

absolute twist is not kinematical, but physical, depending on the fact that there is a structural peculiarity which allows us to identify our generators with surface markings, or on the fact that there is a torsional resistance to change of twist which allows us to define "untwisted." Thus in order to find the change of twist in an initially straight, twisted string, due to any deformation, it is only necessary to mark on the surface a new generator parallel to the axis, and to regard the string as untwisted with respect to this new generator. (To complete a formal proof, the fundamental assumption, that angles in the sections of the string are unaltered by the deformation, must be noted.)

WINDING YARNS ON BOBBINS

The method just discussed of wrapping a yarn round a bobbin occurs in mule spinning, the winding of the spun yarn on to the cop being performed by rotation of the latter. In this case, since the inclination of the yarn axis is, in general, small, there is no change in the twist due to winding. There is another method of winding yarns round bobbins which we must now consider, in which the bobbin remains stationary during the process.

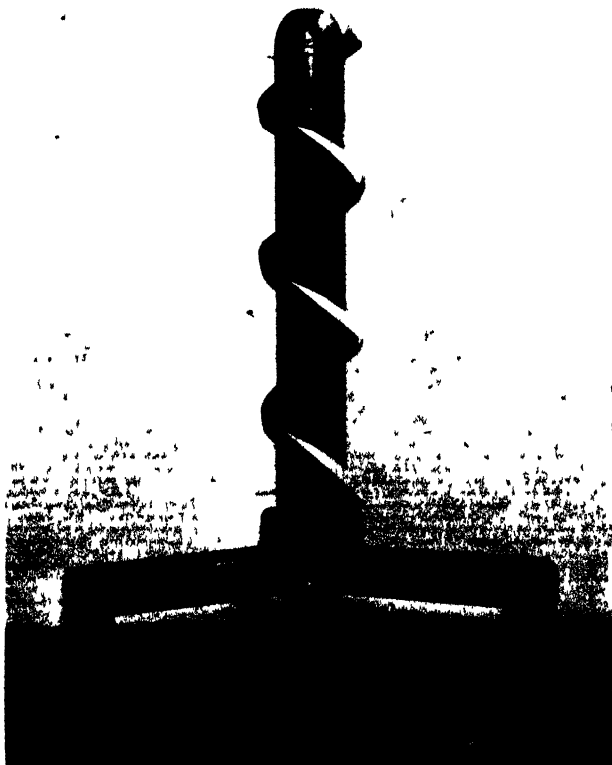


FIG 5—A string wrapped in a helical form round a bobbin (For details of this deformation see text)

Suppose that we have an untwisted string, and that one end of it is fixed to one end of a bobbin. For reference we shall call this end of the bobbin the "foot" and the other end the "nose." Let the foot of the bobbin be held in the left hand with the nose pointing towards the right, and let the free end of the string

be held in the right hand. Then without releasing the grip on the free end, the string can be wrapped round the bobbin. The result of such an operation is illustrated in Fig. 5, in which the foot of the bobbin is at the bottom, and the string was wrapped round the bobbin in the form of a left-handed helix proceeding from foot to nose. A comparison of Figs. 1 and 5 shows that whereas in the former case the same face of the string was in contact with the bobbin at every point, in the latter each face in turn comes into contact with the bobbin, and that this happens once in each turn of the helix. A consideration of the transverses to any generator shows that in Fig. 5 they have an additional rotation about the axis of 360° in each turn of the helix; in other words the twists in the two cases differ by 2π radians per turn of the helices. It is easy to see that the additional rotation in the second case is positive (in the case of right-handed helices it would be negative), so that in Fig. 5 the twist is

$$T = 2\pi (1 - \sin \alpha) \text{ radians} \dots\dots\dots(5)$$

per turn of the helix.

We may describe the process detailed above as "winding the string round the bobbin, from the foot to the nose, over the nose"; "from the foot to the nose" because the helix formed ran in this direction, and "over the nose" because the right hand passed over the nose once for each turn of the helix. Variations of the process are possible in which the winding is from nose to foot, and takes place over the foot. All such variations are tabulated below.

Table I
Variations in the Second Method of Winding

Direction of Winding					Sense of Helix	Twist per Turn of Helix (Radians)	
From	Over the						
1—Foot to nose	Nose	...	Right-handed	...	$-2\pi (1 - \sin \alpha)$
2— " " "	"	...	Left-handed	...	$+2\pi (1 - \sin \alpha)$
3—Nose to foot	"	...	Right-handed	...	$+2\pi (1 + \sin \alpha)$
4— " " "	"	...	Left-handed	...	$-2\pi (1 + \sin \alpha)$
5—Foot to nose	Foot	...	Right-handed	...	$+2\pi (1 + \sin \alpha)$
6— " " "	"	...	Left-handed	...	$-2\pi (1 + \sin \alpha)$
7—Nose to foot	"	...	Right-handed	...	$-2\pi (1 - \sin \alpha)$
8— " " "	"	...	Left-handed	...	$+2\pi (1 - \sin \alpha)$

In these the last four are derived from the first four by interchanging the names of the ends of the bobbin. In every case the winding is supposed to be helical, the inclination of the helix being α .

To each method of winding, whether the first method (rotating bobbin) or any variety of the second (stationary bobbin), there is a corresponding method of unwinding; and it is clear that the change of twist during any unwinding process is equal and opposite to that during the corresponding winding process. By combining different methods of winding and unwinding it is possible to produce a number of effects. For instance, the string in Fig. 1 was wound by the first method into a L.H. helix and so has twist equal to $-2\pi \sin \alpha$ per turn of the helix. Let us call the bottom of the bobbin the foot; then the helix runs from foot to nose if the string is fastened to the foot of the bobbin and free at the other end. It is possible to unwind the string from the bobbin by the second method in two ways, corresponding to variations 2 and 6 in Table I. For the former the foot of the bobbin is held in the left hand and the free end of the string in the right hand; the string can then

be pulled off the bobbin over the nose. The twist due to this unwinding is the reverse of that given in the table in line 2, i.e. is $-2\pi (1 - \sin \alpha)$. Adding this to the twist introduced by the winding, $-2\pi (\sin \alpha)$, we obtain as the final twist in the unwound string just one turn of L.H. twist for each turn of the unwinding*. For the other variation, the *nose* of the bobbin is held in the left hand and the free end of the string in the right; the string can then be pulled off the bobbin over the foot. The unwinding twist is then the reverse of that in line 6 of the table, i.e. is $+2\pi (1 + \sin \alpha)$ per turn of unwinding. Adding the winding twist we get as the resultant one turn of R.H. twist per turn of the helix.

The string in Fig. 5 was wound by the second method, Variation 2. It can be unwound by the same process, in which case the winding twist is reversed by the unwinding; or by the first method, giving a final twist of one turn per turn of unwinding; or by Variation 6 of Table I. The details of this method were given above. The twist due to the unwinding is $+2\pi (1 + \sin \alpha)$; that due to the initial winding was $+2\pi (1 - \sin \alpha)$. The resultant twist in the unwound string is therefore the sum of these, i.e. 4π radians, or 2 turns of R.H. twist for each turn of the unwinding.

As mentioned above, the first method of winding occurs in the mule. It may also be illustrated by imagining that the delivery rate in the ring or cap spinning machines is equal to the rate of winding, so that in the former, for instance, the ring remains stationary. So long as the inclination of the windings is small there is no change in the twist due to winding by this method. Hence in the ring frame the twist in the yarn *on the bobbin* is governed by the rate of rotation of the ring.

If in the flier frame the rate of delivery were equal to the rate of winding, then the bobbin would not rotate and the winding would take place by the second method. Different variations would occur in the same bobbin of yarn corresponding to the upward or downward motion of the bobbin necessary in order to distribute the yarn over its surface. If, for instance, the rotation of the flier is clockwise looking down in the direction of motion of the yarn, then we should get Variation 2 of Table I when the bobbin is moving downwards, and Variation 3 when it is moving upwards. When the inclination of the winding is small, the twist due to winding is therefore 1 "turn" per turn of winding. When the bobbin rotates, as it does during spinning, the twist in the yarn *on the bobbin* is determined by the rotation of the bobbin, together with the extra turn for each turn of winding; this is equivalent to saying that the twist is governed by the rate of rotation of the flier.

From what has been said above, it is clear that the twist in the yarn when it is unwound from the bobbin may be different from what it was on the bobbin, according to the method used for unwinding. In most cases, however, the effects are probably masked by the ordinary irregularities which occur in spun yarns.

TWIST IN MULTIPLE YARNS

When a number of single yarns are twisted together to form a multiple yarn, it is natural to inquire whether it is possible, from a visual examination of the complex so formed, to deduce the initial twists in the constituents. The examination of this problem in the general case is rather difficult, so that attention here will be confined to the relatively simple cases where the axis

* This winding and unwinding operation is the basis of the twisting method employed in mule spinning.

of the constituent under consideration lies in a helix. The most important such case is that of the two-fold, but examples also occur in wire ropes in which single constituents lie in helical form round a central core.

There are two methods of doubling two strings together to form a two-fold, which may be thought of as analogous to the two methods discussed in the previous section of winding a string round a bobbin. Corresponding to the first method of winding (rotating bobbin) we have the normal method of doubling, in which the strings are laid in contact side-by-side and then one pair of ends is rotated about the line of contact, thus deforming the axis of each string into a helix. The two axial helices may be of different sizes; or, in the case of a symmetrical two-fold built from similar components, of the same size. Fig. 6 shows the stages in the formation of a double string (a),

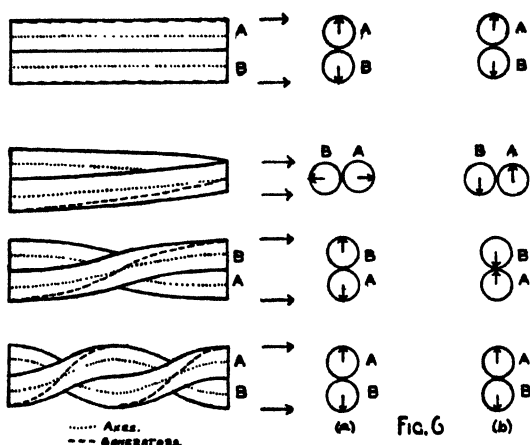


FIG. 6—A diagrammatic representation of the formation of a two-fold from untwisted components (a) by the usual method and (b) by plaiting. In the longitudinal views, the broken lines represent the positions, in case (a), of the two generators to which the transverse are marked by arrows in the end sections.

by the usual method, and (b) by the plaiting method (see below). The initial twists in the constituents are zero; the broken lines represent the positions of a generator of each string when the doubling is performed by the usual method. The end views (a), show how the transverse to these generators in the end sections lie at each stage of the doubling.

There is really more than an analogy between this method of forming a two-fold and the first method of winding a yarn round a bobbin: the two operations only differ in degree, since in both cases the axis of the single string is deformed into a helix, whilst in doing this one end of the string is rotated through 360° about the axis of the helix for each turn of either winding or doubling. The only difference between the two operations lies in the fact that in winding on bobbins the radius of the axial helix is larger than in doubling. Now the result which we obtained for the change of twist due to winding is true whatever the radius of the bobbin; consequently we can apply this result immediately to obtain the change of twist in either component of the two-fold, which occurs during the doubling process. *This change of*

twist is therefore $2\pi \sin \alpha$ radians per turn of doubling.* where α is the inclination of the axial helix. It is only when the doubling twist is small that the change of twist is one "turn" for each turn of doubling twist. The magnitude of the error in omitting the factor $\sin \alpha$ may be considerable; in what is probably an extreme case, when $\alpha=60^\circ$, an allowance of one "turn" per turn of doubling is 15% too large.

The other method of forming a two-fold is illustrated in the end views of Fig. 6 (b). Here the orientation of the end of each string is invariable; just as was the case in winding a string round a bobbin by the second method (Variations 1 and 2 of Table I). The results obtained for that process apply to plaiting as well, the change of twist being $2\pi (1-\sin \alpha)$ radians for each turn of plaiting.

In the general case of a single yarn being a constituent of a multiple one, and having its axis in helical form, the discussion of doubling given above applies *in toto*, so that there is no necessity to consider this case further.

FIBRE-ANGLES IN MULTIPLE YARNS

So far we have been able, by means of observable quantities, to estimate the change of twist in a helical string which is a constituent of a multiple one, due to the operation which embodies the component into the complex. If the single string has generators which are observable, there remains the possibility that from observations on the form of these we can deduce the absolute twist in the deformed string, and thus, since the change of twist due to the deformation is known, the initial twist in the string.

In a recent paper, Schwarz³ has attempted to do this; he assumes that the angle ψ between the surface fibres and the axis, at a point to be defined precisely below, is connected with the twist by the same relation as in a straight yarn,

$$\tan \psi = a \cdot T \quad \dots\dots\dots(6)$$

where a is the radius of the yarn, and the twist is measured in radians per unit length. As we have seen above the extension of ideas based on the properties of straight strings to strings which are tortuous is apt to give misleading results, so that it may perhaps be worth while going into this question here.

The angle ψ under consideration is the angle between a fibre and the axis of the string at that point where the fibre reaches its maximum distance from the axis of the multiple yarn. At this point the angle which the transverse to the fibre (regarding the fibre as lying along a generator of the yarn) makes with the osculating plane of the axial helix is 180° . Fig. 7 shows this angle ψ , the eye being placed on the continuation of the transverse; ψ is positive when the rotation from the axis to the fibre is clockwise, as in the figure; a positive ψ is therefore associated with positive (right-handed) twist in the yarn. The evaluation of ψ in terms of the twist is carried out in the appendix. The result of this calculation in the case under consideration is that

$$\tan \psi = R \cdot T \quad \dots\dots\dots(7)$$

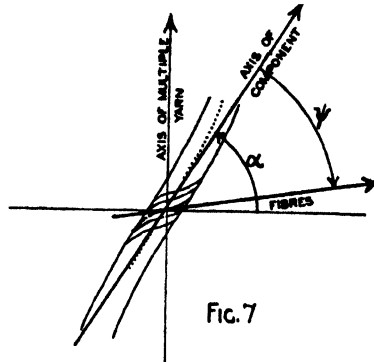
where

$$R = \frac{r \cdot a}{r + a \cdot \cos^2 \alpha} \quad \dots\dots\dots(8)$$

* It is assumed throughout this paper that the length of the axis in a deformed string is the same as when the string is straight. If there is "take-up" in the single strings due to the change of twist in the deformation, a modification of this statement is necessary. The change in the total twist in that length of the single string which forms one turn of the two-fold would then be $2\pi \sin \alpha$ radians.

In this, r is the radius, and α the inclination, of the axial helix, and T is the twist in the yarn, measured as usual in radians per unit length. T is to be calculated from (3). It appears, from a consideration of (8), that (6) can be used as an approximation so long as either r is large compared with a , or α is near 90° . In either case the yarn is nearly straight. The difference between (6) and (7) is greatest when r is comparable with a , as for instance, it is in a two-fold. If $r=a$, then $R=a/(1+\cos^2\alpha)$, and the error in taking a instead of R may approach 25% for large twists.

In any application of this result, it must be remembered that T is the twist as given by (3).



It is thus theoretically possible to deduce the initial twist in the component from observations on its form in the complex. As an illustration of this we may consider the case of a symmetrical two-fold, the components having initially n turns per unit length, and the doubling twist being m turns per unit length, both of these being right-handed (in case either of them is left-handed, it is only necessary to change the sign of n or m). The change of twist in the components due to doubling being $2\pi \sin \alpha$ per turn of doubling,* and the length of each component in a turn of the two-fold being $2\pi a \sec \alpha$, we have as the change of twist per unit length $\frac{1}{a} \cdot \sin \alpha \cos \alpha$ radians.

Now since there are m turns of doubling twist in unit length, we have $\cot \alpha = 2\pi ma$; substituting for α the change of twist is $\frac{2\pi m}{1+4\pi^2 m^2 a^2}$. The initial twist in the component was $2\pi n$, so that

$$T = 2\pi \left(n + \frac{m}{1 + 4\pi^2 m^2 a^2} \right). \quad \dots\dots\dots (9)$$

Putting $r = a$ in (8), we obtain

$$R = \frac{a}{1 + \cos^2 \alpha} = \frac{1 + 4\pi^2 m^2 a^2}{1 + 8\pi^2 m^2 a^2} \cdot a \quad \dots\dots\dots (10)$$

and substituting (9) and (10) in (7),

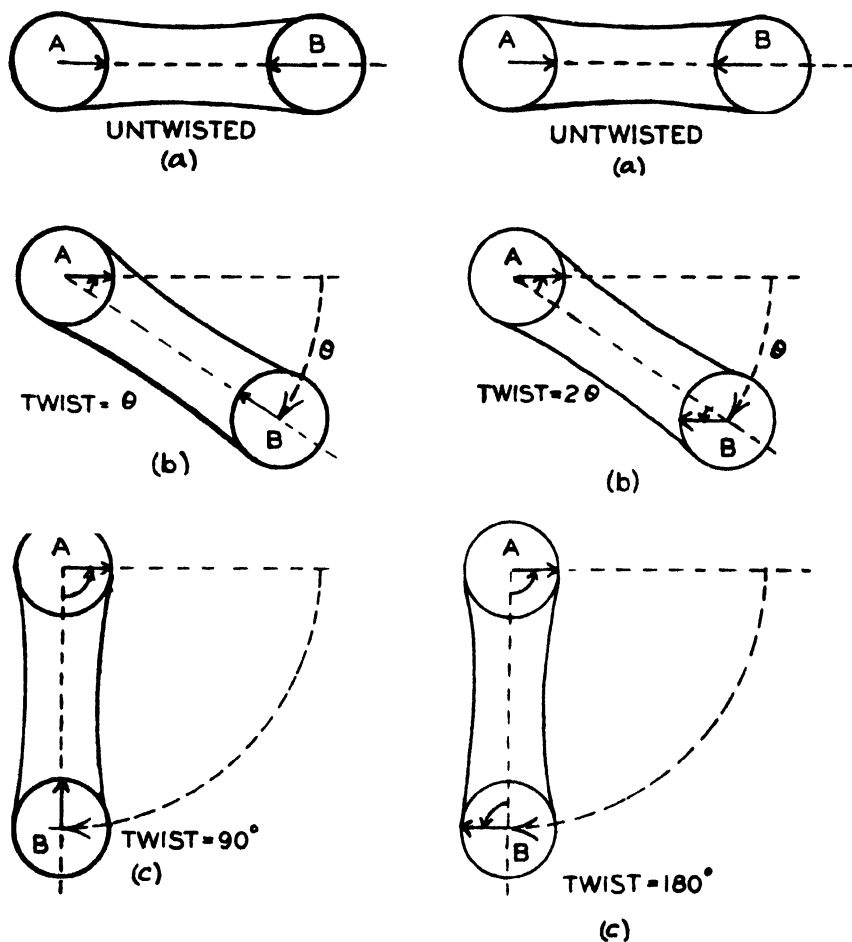
$$\tan \psi = \left\{ \frac{1 + 4\pi^2 m^2 a^2}{1 + 8\pi^2 m^2 a^2} \cdot a \right\} \times 2\pi \left\{ n + \frac{m}{1 + 4\pi^2 m^2 a^2} \right\}$$

from which

$$n = \frac{1}{2\pi a} \cdot \frac{1 + 8\pi^2 m^2 a^2}{1 + 4\pi^2 m^2 a^2} \cdot \tan \psi - \frac{m}{1 + 4\pi^2 m^2 a^2}. \quad \dots\dots\dots (11)$$

* See footnote on p. T327. For yarns exhibiting "take-up," n , in (9) *et seq.* should be multiplied by the ratio of the length of the axis of the component, when straight, to its length when deformed.

This result can be used not only for the purpose proposed by Schwarz, but also in order to calculate the amount of the doubling twist necessary in order to give ψ any required value. For instance, in order to make the outside fibres parallel to the axis of the two-fold, that is, to make $\alpha - \psi = 90^\circ$ (see Fig. 7), we must have $\tan \psi = -\cot \alpha = -2\pi ma$. Putting this value in (11), we obtain at once the result that $n = -2m$, or the doubling twist must be half of the initial twist in the components, and must be in the opposite sense.



FIGS. 8 and 9

SOME OTHER METHODS OF TWISTING STRINGS

As illustrations of the general principles discussed above, a few operations which can be used to insert twist into a string may be mentioned. Consider first the case of a string hanging in the form of a loop. By the general principle stated above that the change of twist due to any deforming operation is independent of the initial twist in the string, we may, without loss of generality, take an initially untwisted string. Figs. 8. and 9 show plans of such a

string. In each figure (a) represents the untwisted string, the transverses at the ends being marked by arrows; they lie in the plane of the string. Fig. 8 (b) and (c) show stages in the rotation of the end B of the string round A; in this rotation the transverse at B remains always in the plane of the string. That at A, however, becomes inclined to that plane, the inclination being equal to the angle through which the plane has rotated from its original position. An application of (r) shows that the twist in the string at any stage of the rotation is also equal to this angle; in other words, a turn of twist is put into the string by each complete rotation of B round A.

In Fig. 9, B is represented as being translated round A. Here, as is evident in (b) and (c), both transverses become inclined to the axial plane, and the twist in the string when the plane has turned through any angle is just twice that at the corresponding stage in Fig. 8. A complete translation of B round A therefore puts two turns of twist into the string.

If in either of these figures we imagine that the arm of the loop ending at B is continued upwards to a point C, and that the revolution of B round A takes place as before whilst C is held fixed, then we perform the operation which is the basis of *loop spinning*. In the case of a translation of B it is clear that the result is the same as before, the twist being two turns (right-handed) for each revolution of B. The other case gives the same result; it is immaterial whether B is rotated or translated round A; the result is the same for both. The essential part of this operation is the passage of the loop completely round, or over, one end of the string. Such an operation always gives a change of twist of two turns for each such passage.

Mention was made above of the fact that winding a yarn round a bobbin by the second method over one end of the bobbin and unwinding it over the other end changes the twist in the yarn by two turns for each turn of the winding. This can be made the basis of a method of putting any required amount of twist into a yarn simply by winding the yarn backwards and forwards from one bobbin to another, as follows—Call the bobbins A and B, and suppose that initially A contains a certain length of yarn, whilst B is empty. We can transfer the yarn from A to B by means of two fliers, one of which winds the yarn on to B after it has been unwound from A by the other (the bobbins remaining stationary). A single such operation will change the twist in the yarn; but if the yarn is wound back on to A by reversing the sense of rotation of the fliers, the consequent change of twist will just annul the former. If, however, instead of reversing the fliers, they are kept rotating in the same sense, whilst the full bobbin B is turned upside-down, then the yarn will unwind from B and pass back on to A. The winding on to B was over the opposite end of the bobbin from that over which the unwinding is carried out; consequently this winding and unwinding puts two turns of twist into the yarn for each turn of the winding. When A is full again, it is in turn reversed, so that the yarn is again transferred to B. This cycle can be repeated indefinitely; each time a bobbin becomes full, it is simply turned upside-down, whereupon the yarn is unwound from it, and passes back to the other. The changes in the twist will be found to be always in the same sense, so that by this means any required amount of twist can be put into the yarn without any rotation of the bobbins.

It is not suggested that this is a practical spinning method, for amongst other objections to it is the fact that it does not twist uniformly—it is rather given as an illustration of how the ideas here developed may be used as a

guide in determining whether any operation can be used as a method of twisting.

CONCLUSION

In conclusion, it is necessary to emphasise the fact that a practicable theory of twist can only be given in the case of ideal strings. The validity of the results so obtained may be seriously endangered if it is attempted to apply them indiscriminately to imperfect structures such as worsted or woollen yarns. Variability or indefiniteness of yarn diameter, take-up due to change of twist, radial compression of the yarn, and fibre slippage are some of the ways in which such a yarn can depart from the ideal. At best, then, the theory can only apply approximately to such a structure; at worst, the very meaning of the term "twist" may be in question.

Particular caution is necessary in those cases where the surface fibres of the yarn are to be assumed to lie on generators; if, however, such quantities as "fibre angles" are to be used at all, there is no alternative to making the assumption, and giving the results for what they are worth.

APPENDIX

The Angle between the Generator and the Axis at any point of a Tortuous String

Take the point on the axis of the string as origin, and take as co-ordinate axes the tangent (x), principal normal (y), and bi-normal (z) of the axial curve at the origin. At each point of the axis let another system of axes be constructed, one pair being the tangent to the axial curve and the transverse to the generator considered. Then in passing along the axis, this second set of axes moves as a rigid body; its motion consists of a translation along the axis together with instantaneous rotations about the tangent and binormal of the axial curve. In passing from the origin to a point ($ds, 0, 0$) along the axis of the string, the motion consists of (i) the translation ds along the x -axis,

and (ii) rotations $T \cdot ds$ about the x -axis, and $\frac{ds}{\rho}$ about the z -axis, where T is

the twist in the string and ρ is the radius of curvature of the axial curve at the origin.

Let the transverse at the origin make an angle φ with the y -axis, that is, with the principal normal at the origin, and let a be its length. Then the co-ordinates of the point where it meets the generator are ($0, a \cdot \cos \varphi, a \cdot \sin \varphi$). The components of the motion of the end of the transverse due to the rotations (ii) specified above are therefore $(-a \cdot \cos \varphi \cdot \frac{ds}{\rho}, -a \cdot \sin \varphi \cdot T \cdot ds, a \cdot \cos \varphi \cdot T \cdot ds)$. Adding to the first of these the amount of the translation (i) we obtain as the components of the corresponding small length of the generator $(ds - a \cdot \cos \varphi \cdot \frac{ds}{\rho}, -a \cdot \sin \varphi \cdot T \cdot ds, a \cdot \cos \varphi \cdot T \cdot ds)$. These are therefore the direction ratios of the tangent to the generator. If ψ is the angle between this tangent and the x -axis, we have at once

$$\cos \psi = \frac{ds \left(1 - \frac{a}{\rho} \cos \varphi \right)}{\left[ds^2 \left(1 - \frac{a}{\rho} \cos \varphi \right)^2 + a^2 T^2 ds^2 \right]^{\frac{1}{2}}} = \frac{1 - \frac{a}{\rho} \cos \varphi}{\left[\left(1 - \frac{a}{\rho} \cos \varphi \right)^2 + a^2 T^2 \right]^{\frac{1}{2}}}$$

and therefore

$$\tan \psi = \frac{aT}{1 - \frac{a}{\rho} \cos \varphi}.$$

In the case considered in the text, $\varphi = \pi$ and $\rho = r \sec^2 \alpha$; and putting in these values we have

$$\tan \psi = \frac{aT}{1 + \frac{a}{r} \cos^2 \alpha} = \frac{a \cdot r \cdot T}{r + a \cos^2 \alpha},$$

which is equation (7) of the text.

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31—FIBRE GROWTH PHASES IN A SAMPLE OF AUSTRALIAN MERINO WOOL

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The lack of conformity in the conclusions drawn from studies on fibre and fleece growth rates is apparently not wholly attributable to the several techniques employed. The confusions have recently been indicated by Burns (1931 *a* and *b*) and Fraser (1931) in their reviews of previous literature, but examples are of interest here to show that the divergences are also not entirely due to the different fibre characters investigated.

Burns (1931 *a* and *b*) adopted a method of monthly growth clippings (checked against the measurement of the straight lengths of 25 fibres from each sample) to study length growth rate in Rambouillet, Hampshire, and Corriedale ewes. He found that growth in the first two types tended to be regular throughout the year, and that over the four years of experiment, the total yearly growths were the same, although the length produced in the first six months after shearing was slightly more than in the next six months, there being an average difference of 9 per cent. From his data on the Rambouillet ewes it emerges that shearing, as reflected in the length grown during the first succeeding month, has no significant effect compared with that during the other months of the year. The Corriedale ewes showed greater variability in monthly and seasonal growth than the Rambouillets and Hampshires. He suggests that fluctuations could be due to nutritional and health causes, and to the course of reproductive activities.

In general Burns' conclusions regarding the Rambouillets agree with those of Hackedorn and Sotola (1929), and differ from those of Hardy and Tennyson (1930) who found variability in wool growth throughout the year. Duerden and Maré (1931) observing a South African Merino lamb for 30 months from birth, record practically the same average monthly growth (of 25 fibres) over the period, with a small increase in the end of winter and early spring.

On the other hand, in a more comprehensive series of observations involving groups of about 30 Merino wethers, and measuring 20 fibres from each small sample, Duerden, Murray, and Botha (1932) found coefficients of variability in monthly growth rates of 26.0% in the first 12-month period, 16.6% in a second 12 months, and 9.3% in a third period of six months which covered only the summer season. They point out that while some of this variation was no doubt due to the use of adjacent staples for measurement, most of it was associated with nutritional changes. The body weight and monthly rate of fleece growth showed direct responses to the grazing conditions, the growth being longer in the summer than in the winter.

Again Fraser (1931) in a study of the mean staple length at monthly intervals of ten Merino wethers in South Australia, observed that the growth of the staple was uniform, although the body weight varied widely during the year, according to changes in the nutritive value of the pasturage. He suggests that the effect of such environmental changes "is reflected in the thickness of the wool fibre and not in the staple length."

Regarding this suggestion, observations on thickness changes in the staple have been made by several authors. Duerden and Bosman (1927) as a result of measurements made on sections from the top, middle, and base of seven

samples of Merino wool state that "the fleece of the Merino rarely grows uniformly throughout the 12 months." In the sample showing the greatest differences between top, middle, and base, the mean fibre "diameters" were 24.1, 27.6, and 19.1 μ respectively. Another sample showed very little change with mean diameters 21.7, 21.6, and 21.4 μ . In six out of seven the base sections were the finest, and it was concluded therefrom that growth was less vigorous towards the end of the season. Norris and Claassens (1931) found that while length increased uniformly, thickness, as measured by the product of the major and minor axes of the fibre, was influenced by seasonal conditions. For five fibres of 31 months' growth, the mean curve of thickness showed differences between the maxima and the minimum point (as zero) of 87, 100, and 150%.

Length and thickness have also been studied by Wilson (1931) in three Romney wethers kept on a fattening ration, and later on a sub-maintenance ration; from the measurement of 50 fibres from small monthly samples, the average total growth in six months was found to be 10.71 cm. on the former, and 7.59 cm. on the latter, while the mean diameter at the base of 100 fibres each from shoulder and britch samples was 26.7 μ at the end of the full feeding stage, and 21.1 μ for the sub-maintenance period, a difference of 26.5%. Similarly, Weber (1932) in the case of two individuals changed in the course of an experiment from a low to a high plane of nutrition, found increases of 15% in diameter and of 14% in length; two others changed from high to low planes exhibited decreases of 30% in diameter and 23% in length.

Changes in fibre thickness, or "diameter," along the staple are commonly observed in the field, and are frequently attributed to alterations in the nutritive supply to the active follicles. Shedding may be an extreme manifestation of sudden drastic changes in activity occurring in practically all follicles simultaneously, but less severe cases may be exhibited as the familiar "breaks." If the length growth rates of the majority of the fibres are alike during subsequent elongation, the break region retains its form as a well-defined band running transversely across the staple, but if the rates vary widely (as in many longwools and crossbreds) the distinct line of break tends to be lost and a "tender zone" established. Clean partition of the staple under stress does not take place in the latter circumstances, since the location of the "break" on any one fibre in the staple will change relative to that on any other according to their respective length increments, the difference being emphasised as growth proceeds. In some instances the altered level of production persists for some time, and the staple may show successive zones of different "qualities" especially in the less heterogeneous wools such as most Merinos, and opportunity is available to examine the magnitude of the effects which may be produced in fibre growth.

While different rates of follicle activity need not be manifested in one direction only, alterations in thickness and length probably being correlated, the former appear the more obvious, and other concomitants of growth changes tend to be overlooked.

In ordinary examination of wools, the least obvious would be a change in activity expressed predominantly as an alteration in length growth rate; yet there is evidence that this phenomenon may often occur. Indeed from the point of view of the sheepbreeder regarding his great problem of reducing the effects of environment upon wool characters, it would seem to be the most important in practice.

MATERIAL

Through the courtesy of Sir Graham C. Waddell and Mr. J. Culley, a sample of wool was secured from the 1926 clip of a station in the Hay district of New South Wales (Plate I). Unfortunately, detailed information on rainfall, pasturage, and cognate environmental conditions is not available. A similar sample to that illustrated, but of slightly shorter staple, was used for examination.

In the total staple length of 10.5 cm., three portions of markedly different characters could be distinguished, a "tip" fraction 3.3 cm. long, a "middle" with length 2.7 cm., and a "base" of 4.5 cm. The staple crimps in each fraction were clearly defined except in the narrow zones in which the character changes took place. The staple crimp numbers were respectively 10, 11, and 10.

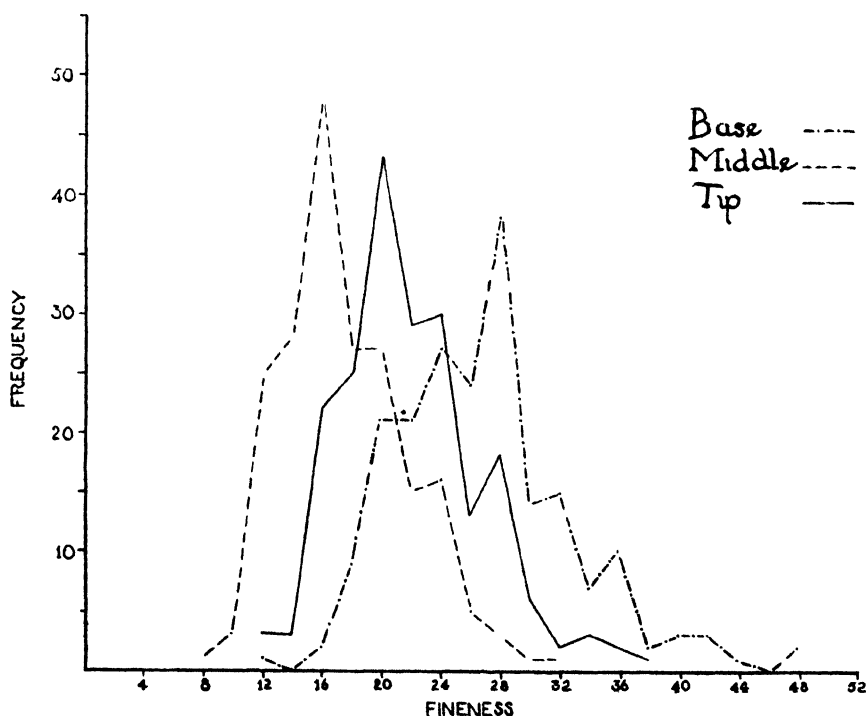


FIG. 1

As only a relatively small amount of wool was available for analysis, a sub-sample was removed for length and fineness determinations. The greater part of the original sample was divided into tip, middle, and base fractions by careful section with sharp scissors along the two bands of character change. These fractions were twice zoned independently, the fibres selected in the first zoning being used to provide clippings for thickness estimation after Duerden's method, and those of the second for length and fineness measurement by Roberts' method (1930).

In the former, short fragments were cut from towards the ends and in the centres of each bundle of fibres from the first zoning. The small portions representative of each staple fraction were thoroughly mixed during washing with benzene and xylol, and then mounted for microscopical measurement. The results of 200 observations for each fraction are shown in Table I.

Table I

Fraction			Mean Fineness in μ	Coefficient of Variation %	Standard Error of Mean
Tip	...	...	21.98	21.40	± 0.33
Middle	...	...	17.57	24.20	± 0.30
Base	...	...	26.92	22.35	± 0.43

The significant differences in fineness ("diameter") between the successive fractions are apparent; between tip and middle there is a decrease in "diameter" of 20.1% and between middle and base an increase of 53.2%. The percentage frequency distributions of fineness in each fraction (see Fig. 1) are very similar, especially in "tip" and "middle," suggesting that the constitutions of the fraction populations in respect of diameter were much alike, and that the influences leading to the changes in "diameter" have been effective throughout the fibre population. The middle fraction shows, however, a somewhat greater variability than the others—possible reasons for this are indicated below.

In the course of the examinations by Roberts' method, the number of crimps per fibre fraction and the crimped (unstretched) lengths were also recorded. The relevant data are summarised in Table II.

Table II

Fibres Measured		Mean Length	S.D.	Mean Crimped Length	S.D.	Mean Crimps	S.D.	Fineness
		cm.		cm.				cm/mg.
Tip Fraction	72 (1 in 5)	4.25	± 0.62	3.38	± 0.40	13.88	± 2.10	247.5
Middle Fraction	72 (1 in 5)	4.06	± 1.00	3.07	± 0.44	13.60	± 2.24	351.2
Base Fraction	72 (1 in 5)	5.32	± 0.59	4.55	± 0.41	15.25	± 1.95	180.7
Whole Lock	50 (1 in 3)	13.54	± 2.44	10.42	± 1.49	36.5	± 5.43	231.6

Regarding the "whole lock" sample it must be emphasised that this was actually a separate lock; its data, therefore, are not strictly comparable to those from the fractions, which were transverse sections of the same locks.

DISCUSSION

It is presumed that the sample is the result of approximately a year's growth. Since all lengths of fibres from 7.5 to 18.0 cm. were found in the "whole lock," the fibre growth rates had been very variable. This is also shown by the relatively ill-defined nature of the distal "break" zone. Hence it would be anticipated that the fibre fractions need not necessarily correspond to the staple fractions and that the middle fraction would include some portions of fibres actually produced during the period of growth of the tip fraction and these would probably serve to increase the variability of fibre length within the former. The percentage frequencies of fibre length groups



PLATE I

(in 0.5 cm.) are plotted in Fig. 2, the graphs being presented both superimposed and in succession. (The greatest length in the base fraction was 6.5 cm., the shortest in the middle fraction was 2 cm., the graph for the latter has therefore been begun 2 cm. from the end of the former, etc.) The greater variability in the middle fraction is clearly shown. But in so far as the fibres would be more likely to be disposed in the staple according to their crimped lengths, the variability in respect of this measurement would tend to be reduced to about the same order in each fraction. The coefficients of variation of uncrimped and crimped lengths are respectively "tip" 14.5 and 12.0, "middle" 24.6 and 11.2, and "base" 11.0 and 9.0 per cent.

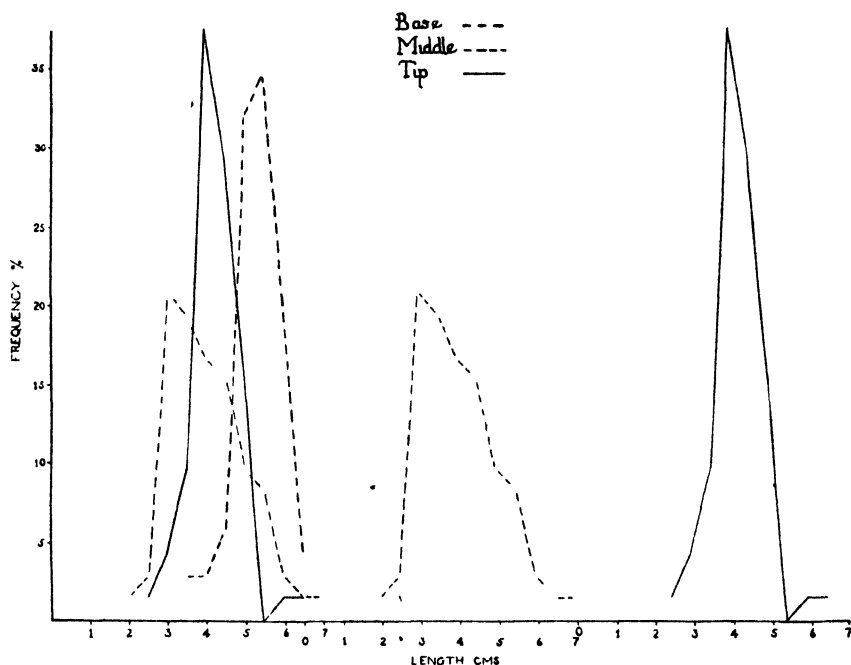


FIG 2

In the absence of information on the time taken in the production of the several phases, resort is made to estimation based upon the findings of Norris and van Rensburg (1930) that crimp is a function of time. Using mean lengths and mean crimp numbers the relative growth periods for each fraction are seen to be tip 3.9 months, middle 3.8 months, and base 4.3 months, the fibres having lengthened on the average by about 1.09, 1.07, and 1.24 cm. per month during the different phases. The same order of growth periods is obtained if the staple lengths and staple crimps are used; the staple lengthened in the respective times by 0.85, 0.71, and 1.05 cm. per month. Another comparison of the length growth rates in the different periods may be obtained by calculating the mean fibre length per crimp, the values being tip 0.31 cm.; middle 0.30 cm.; and base 0.35 cm.

The development of the staple during the course of the year is illustrated diagrammatically in Fig. 3, in which, alongside the diagram of mean straight length increases, are shown sketches of the mean crimped length and the staple appearance at the end of the year's growth.

Using length per unit weight to express the fineness of the fractions, it may be seen from Table II that the change from the tip fraction to the middle, involves an increase of 103.7 units, and from the middle to the base occurred a decrease of 170.5 units; that is, in centimetres per milligram, the successive changes during the growth of the staple were of the orders of 42% increase and 49% decrease. The main point, however, is the form assumed by the wool substance during the three growth phases and a clearer picture of this can be obtained by utilising these fineness values to calculate the mean volume per fibre produced in each period. For this all the necessary data are accumulated in the course of analysis; mean fibre volume is proportional to mean length (l) divided by fineness (F) if the density of the wool substance is considered constant throughout the fibre population represented by the sample. In terms of mean fibre volume units (i.e. $\propto l/F$) the values for the fractions are tip 0.017, middle 0.012, and base 0.029, involving successively a decrease of 29% and an increase of 142 per cent.

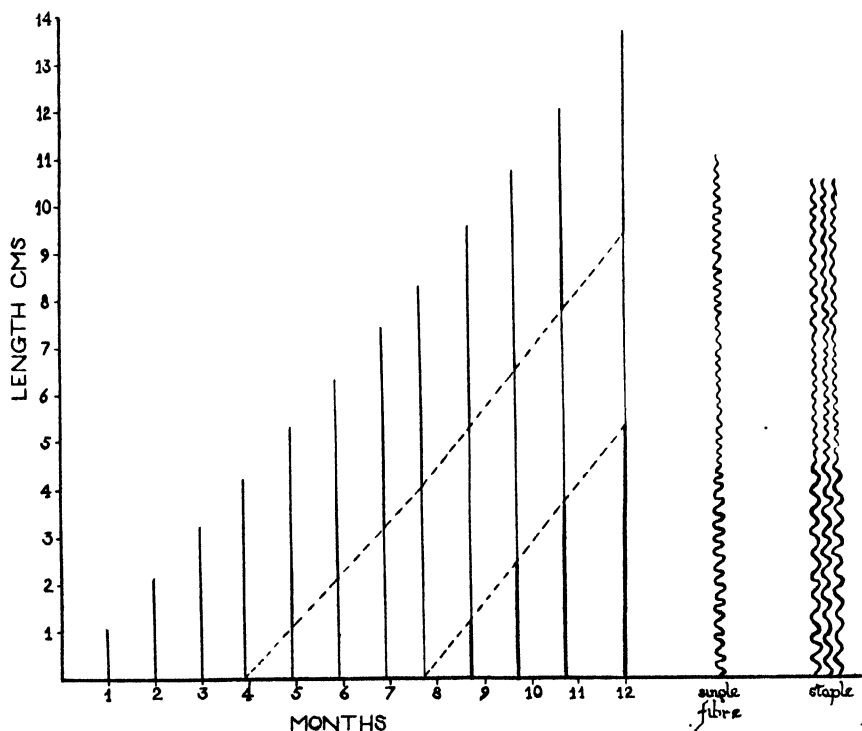


FIG. 3

The differences in mean length grown in the periods (see Table II) were tip-middle a decrease of 0.19 cm. or 4%, and middle-base an increase of 1.26 cm. or 31%. Since length contributes directly to volume changes in cylindrical forms (while diameter contributes according to its square), an estimate may be made of the relative importance of the length and thickness variations.

Thus as between the tip and middle fractions the mean fibre volume decreased by 29%, the length changing by 4%, the contribution due to the different thickness was 25%, and between middle and base with an alteration of 31% in mean fibre length, the proportion of volume change due to thickness was 111% (the diameter changes $\propto \frac{l}{\sqrt{F}}$ were of the order of -16% and +39 per cent.).

Similarly the differences in mean fibre length and volume produced per month (using, as above, crimps as a function of time) can be determined as tip-middle, -0.02 cm. or -2% and -0.0008 volume units or -27%; middle-base, +0.23 cm. or 21% and +0.0035 volume units or +109%. From which the contributions due to altered thickness may be said to be -25% and +88 per cent.

CONCLUSIONS

The wool follicle displays great flexibility in the manner of its response to conditions affecting its rate of activity, and maintains the continuity of its production of fibre material under wide changes of metabolism. In this sample the average rate of production per month (in terms of volume) in the second growth period was approximately two-thirds that during the first period while between the second and third phases a sudden acceleration to a rate over twice as great was manifested. In view of the fact that these changes in volume are not contributed to by thickness and length rate in the same proportion at each alteration in activity, it would seem desirable that the relative importance of the different responses should be considered in studies on factors influencing wool production. (Where medulla formation is included in fibre growth, the balance of cross-sectional area and length rate changes might be more grossly disturbed.)

It can be suggested that the discrimination between cases in which variations in metabolism are accommodated chiefly by alterations in thickness of fibre and those in which length growth rate is predominantly affected, would be of particular application in the selection of sheep for habitats where seasonal effects are frequent or usual.

SUMMARY

1—References to investigations on the growth rate of wool are considered according to the particular dimensional attributes which have been studied.

2—Detailed analyses are recorded of an Australian Merino sample which shows two well-defined changes in character and quality along the staple.

3—At the times of these changes in character, the rate of elaboration of fibre substance altered greatly; in terms of mean volume per month, production in the second period was 27% less than in the first, and 109% greater in the third than in the second.

4—In these different levels of production, length-rate and thickness did not share in the same proportions at each "break."

5—The desirability is emphasised of considering both thickness change and altered rate of length increase, and of assessing the relative importance of their contributions to the expression of follicle activity in the form of volume of fibre substance.

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TRANSACTIONS

32—SOME STUDIES OF THE YOLK IN NEW ZEALAND WOOLS II—A STUDY OF YOLK IN THE FLEECE DURING ONE YEAR

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INTRODUCTION

The author¹ has previously discussed the occurrence of yolk in the fleece and its possible bearing on the production of wool. The present paper describes an investigation of some aspects of this problem, undertaken with the object of supplying a basis of carefully determined measurements relating to yolk production. It is felt that casual observation cannot supply a true and complete explanation of the function and significance of yolk in the fleece.

This experiment was designed to provide data on the seasonal variations in yolk content of the fleece, and the connection, if any, between yolk and type of wool. This work has now been interrupted, but the results so far obtained may be of interest to other workers.

EXPERIMENTAL

At the beginning of July, i.e. mid-winter, 1929, 40 sheep were chosen from the College flock of Romney Marsh ewe hoggets. Two selections were made, one for a fine wool type and the other for a stronger wool. The counts in the fine wool group were all 48's and 50's, in the strong wool group 44's and 46's. There were originally 20 sheep in each group, but in October 1929 the numbers were increased from the same source to 24 in each group.

A sample was taken from the middle of the side of each sheep as described in the previous report.¹ From each group ten sheep were taken at random and fitted with light waterproof covers. The sheep were then turned out with the hogget flock again.

From the date of selection until the end of October, samples of about 30 grams of wool were taken at approximately monthly intervals, a fresh area being sampled each time, as close as possible to the middle of the side. The dates of sampling were as follows—

Sampling numbers ..	1	2	3	4	5	6	7	8	9
Dates ...	8/7/29	15/8/29	23/9/29	23/10/29	20/1/30	24/2/30	2/4/30	3/5/30	3/6/30

At the end of October each sheep was carefully examined for various wool characters, sampled, and then shorn in the manner customary in New

Zealand with the machines. The covered sheep were immediately re-covered. The sheep were not dipped, as the effect of dipping on yolk was not known. No infestation with any kind of parasite occurred.

At the end of January 1930 there had been sufficient growth of wool to enable a sample to be taken from a reasonably small area, and sampling was resumed and continued as before until June 1930, when the sheep, which had been run with the rams in the autumn, were too heavy in lamb for further handling.

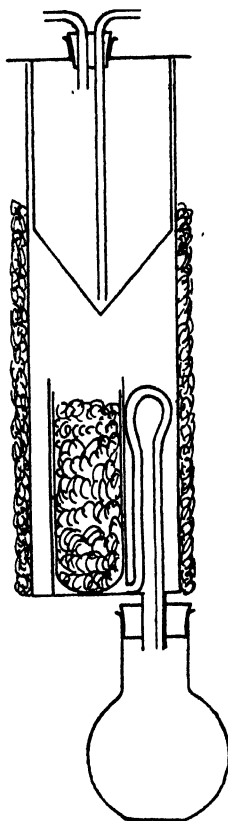


FIG. 1

Sampling was done with the ordinary shearing machines, except on one occasion when scissors were used. The latter are not to be recommended. When using the machines care must be taken not to make "second cuts," as these small pieces of wool get lost in the subsequent handling.

After the wool was long enough the covers were secured by sewing to the fleeces tabs provided for that purpose on the interior of the cover. For some time after shearing, leg-straps and belly-bands were used. The covers did not interfere with the mating of the ewes with the rams and had no ill effects as far as could be seen. That the effect of covers on yolk production is not detectable has been shown in a previous paper.¹

METHOD OF ANALYSIS

The method of analysis has already been described.¹ During the latter part of this experiment a modified form of apparatus (Fig. 1), based on that of Marston,² was used for the water extraction, as the standard glass article failed after a number of heatings. The apparatus finally adopted was made locally, and has proved quite satisfactory. The extractor and condenser are made of heavily tinned copper. The condenser is a simple one, relying for efficiency on its large surface area and the narrow space between its surface and the wall of the extractor. It is so arranged that the condensed water drips off the point on to the thimble of wool below. The extractor consists of a steam jacket to keep the sample warm and to conduct the steam to the condenser, and a thimble holder with the usual siphon tube. The flask is a 250-ml. Pyrex extraction flask and is heated in an oil bath. With this apparatus the progress of extraction cannot be watched as with glass vessels, so that the time necessary for complete extraction must first be determined and all extractions continued for at least this time. The author found 12 hours sufficient in most cases. The apparatus gave just as reliable results as did the orthodox glass apparatus, provided due care was taken to carry the extraction to completion.

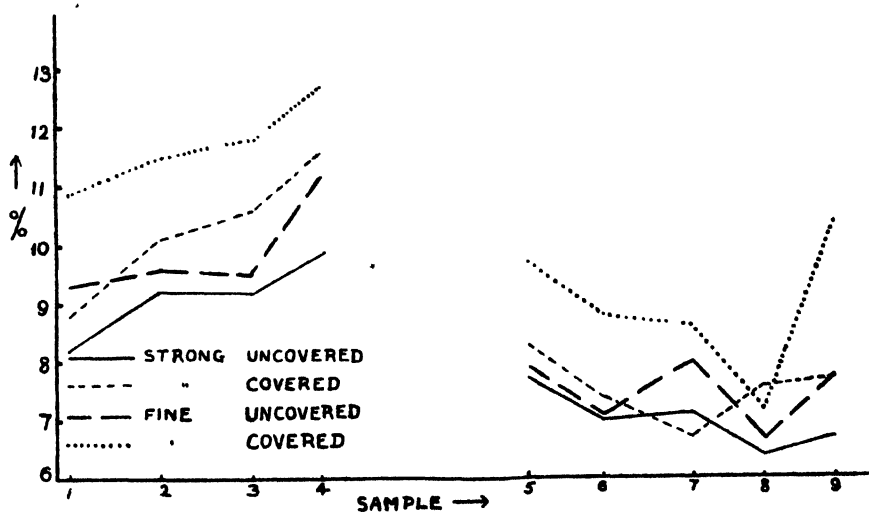


FIG. 2.—Showing average values of ether soluble extract at each sampling for each group of sheep (a) strong-woolled uncovered, (b) strong-woolled covered, (c) fine-woolled uncovered, (d) fine-woolled covered.

RESULTS

The detailed results are given in Tables I and II. In some cases results have been lost through loss of the sample or other accidents. A very few results have been omitted because of discrepancies revealed by a system of internal check. The average values obtained from Tables I and II are given in Table III and graphically in Figs. 2 and 3. In Table III and Fig. 5 the group average values for total yolk are also given, for comparison with the more detailed results for water soluble extract and ether soluble extract.

Table I—Ether Soluble Extract: Percentages

	STRONG-WOOLLED										FINE-WOOLLED									
	Sheep Number	Sample Number								Sheep Number	Sample Number									
		1	2	3	4	5	6	7	8		9	1	2	3	4	5	6	7	8	9
Uncovered	361	6-6	6-8	8-5	8-7	6-6	4-3	5-7	5-7	6-4	383	7-4	8-2	8-7	9-2	7-4	5-2	8-0	6-5	6-6
	363	9-4	10-9	10-3	—	—	—	—	—	—	386	10-6	11-5	11-0	12-6	7-8	8-5	8-0	7-5	8-2
	366	6-7	7-8	7-7	8-2	5-8	4-2	5-9	5-8	6-3	388	7-2	6-8	6-2	7-7	5-2	—	6-4	5-1	5-3
	367	9-1	9-4	9-7	11-6	8-6	—	7-6	7-3	7-2	389	9-6	9-7	10-8	10-0	8-5	6-4	6-4	7-3	8-1
	369	6-8	8-1	8-3	8-9	7-0	—	5-6	5-8	6-2	391	11-7	13-1	—	—	—	—	—	—	—
	373	8-6	11-6	10-2	11-0	9-1	6-8	7-0	6-4	6-2	392	10-8	9-3	10-1	11-5	8-1	6-3	9-2	7-6	7-0
	375	8-6	9-6	9-6	6-7	5-5	—	6-1	6-3	—	395	9-2	9-5	10-3	9-5	9-9	8-0	9-8	7-7	—
	376	9-7	9-3	9-6	10-0	6-8	9-3	6-7	5-2	5-7	397	6-8	7-5	9-7	9-9	8-9	10-2	10-0	11-1	11-8
	378	9-0	10-7	9-6	10-8	10-2	11-9	—	8-7	8-9	399	9-8	9-6	7-4	11-3	9-4	6-0	—	4-6	7-7
	379	7-5	8-3	7-9	9-5	6-5	7-1	7-1	5-7	5-9	487	9-5	10-4	11-7	11-5	8-6	8-9	8-7	6-4	7-1
	810 ^a	—	—	—	—	8-8	7-9	9-7	7-8	8-8	804	—	—	—	—	11-3	7-5	5-5	7-6	5-5
	823	—	—	—	8-9	8-2	5-7	8-8	5-7	5-7	805	—	—	—	—	12-4	7-0	—	7-8	5-9
											806	—	—	—	—	17-1	7-0	8-2	7-8	6-4
										807	—	—	—	—	—	6-9	5-0	6-8	5-2	
Covered	358	6-1	8-0	8-7	—	7-8	8-8	10-9	—	8-4	381	10-7	11-1	11-3	12-0	9-9	8-6	7-6	6-3	8-8
	364	12-1	12-6	12-6	13-6	10-4	9-7	8-3	8-5	—	382	12-8	13-2	13-7	15-0	15-3	13-0	13-0	—	12-8
	365	8-9	11-3	12-1	—	8-8	7-5	7-9	—	7-0	384	8-4	9-0	8-8	9-6	6-5	5-4	6-6	6-4	—
	368	8-5	9-1	—	—	8-4	6-7	5-5	7-1	6-3	385	13-5	13-8	13-4	16-8	9-6	7-4	7-3	7-0	10-0
	370	9-0	10-9	10-4	11-2	9-2	7-4	6-6	—	—	387	10-8	12-7	13-4	12-5	12-9	9-0	6-1	8-6	8-8
	371	11-7	13-6	13-0	14-0	8-7	10-2	4-7	8-6	9-3	390	7-8	8-7	9-8	7-7	6-3	—	—	5-1	7-1
	372	7-6	9-4	10-5	—	7-6	6-5	7-7	—	7-9	393	10-8	11-2	11-9	11-5	9-2	9-8	11-9	—	12-4
	374	7-6	8-4	9-6	10-2	9-8	6-7	5-5	8-6	8-9	394	10-6	11-2	11-8	12-9	10-4	9-0	9-7	9-6	11-1
	377	7-7	8-8	8-7	—	7-7	5-3	3-1	6-5	6-2	396	12-4	12-6	12-4	14-8	8-2	8-7	—	8-6	12-6
	380	9-0	8-8	10-1	9-1	7-5	—	7-3	7-5	7-5	398	11-3	11-4	11-9	12-7	9-6	10-6	8-5	6-2	9-8
	812	—	—	—	—	4-3	6-8	—	6-6	6-9	808	—	—	—	—	8-5	6-2	6-3	—	—
	818	—	—	—	—	8-6	7-2	6-6	6-8	8-4										
	363	—	—	—	—	9-6	6-0	6-5	8-5	8-3										

Table III—Average Total Yolk: Percentages

Ether Soluble Extract

Strong-woolled	Uncovered	8.2	9.2	9.2	9.9	7.7	7.0	7.1	6.4	6.7
	Covered	8.8	10.1	10.6	11.6	8.3	7.4	6.7	7.6	7.7
Fine-woolled	Uncovered	9.3	9.6	9.5	11.2	7.9	7.1	8.0	6.7	7.7
	Covered	10.9	11.5	11.8	12.7	9.7	8.8	8.6	7.2	10.4

Water Soluble Extract

Strong-woolled	Uncovered	12.3	11.5	15.2	17.6	7.9	13.2	13.6	9.4	12.4
	Covered	12.6	16.1	16.3	19.3	16.3	19.4	18.5	15.0	18.7
Fine-woolled	Uncovered	14.1	12.7	14.9	19.1	9.6	15.9	15.3	9.2	13.6
	Covered	14.8	16.2	18.9	20.6	19.5	21.0	19.5	13.5	22.0

Total Yolk

Strong-woolled	Uncovered	20.5	20.7	24.4	27.5	15.6	20.2	20.7	15.8	19.1
	Covered	21.4	26.2	26.9	30.9	24.6	26.8	25.2	22.6	26.4
Fine-woolled	Uncovered	23.4	22.3	24.4	30.3	17.5	23.0	23.3	15.9	21.3
	Covered	25.7	27.7	30.7	33.3	29.2	29.8	28.1	20.7	32.4

DISCUSSION

In view of the fact that the sheep were deliberately selected for fine and strong wool characters, without any regard to the distribution of fine and strong wool throughout the flock, and also in view of the small numbers necessarily observed, great care should be exercised in interpreting and applying the results. It is not known that these sheep were representative of the College flock, or that the College flock is typical of New Zealand Romney Marsh flocks in general in so far as yolk production is concerned.

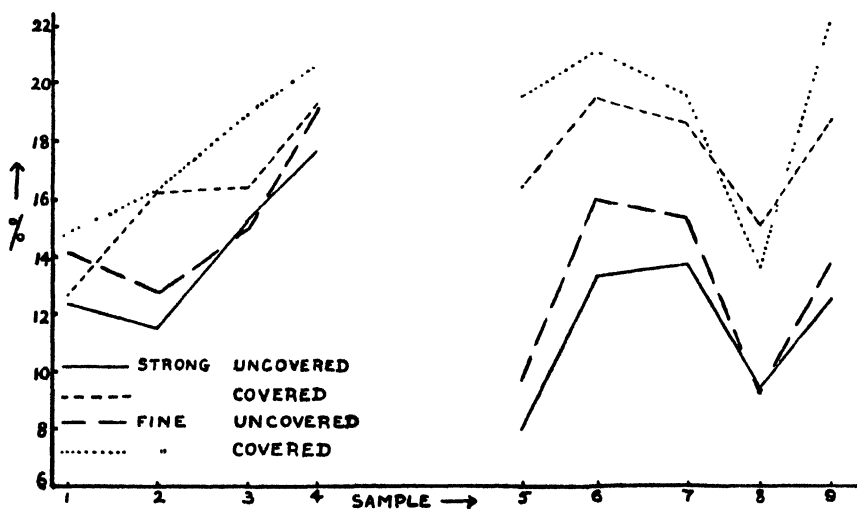


FIG. 3—Showing average value of water soluble extract at each sampling for each of the four groups of sheep.

There is a point involved in the method of calculation of yolk content of which the importance has only been realised as the result of other work carried out since the beginning of this experiment. The yolk content has been expressed as a percentage of the clean dry fibre, not of the raw greasy wool, for reasons previously explained.¹ However, the yolk content as thus expressed is the resultant of two factors, (1) rate of production of yolk, and (2) rate of growth of wool fibre. So that such yolk content can be a true index of yolk production only if the second factor is constant. If the rate of growth of wool fibre, though not constant, were known, the true rate of yolk production could be derived from the yolk content as above determined.

So far opinion seems to be divided on the question of rate of growth of wool, and it is not the function of this paper to review the extensive work on this aspect of wool production in various breeds. However, Waters³ has shown that the rate of wool growth on certain sheep in the flock at the Massey Agricultural College is extremely variable. It is thus important to consider the possible variations due to this cause.

Waters made measurements of the growth rate of wool at different times of the year on eight New Zealand Romney sheep. We will consider the relative rate of growth for two consecutive periods only, namely a 14-week period preceding the middle of April, and the 14-week period from the middle of April to the middle of August, since this range of time covers some important changes in yolk content of the fleece described in this paper. Waters' measurements deal only with growth in length. Expressing the growth for the second period as a percentage of that for the first period, he obtained the following results—

Sheep Number	...	...	1	2	3	4	5	6	7	8
Percentage	...	...	83	80	72	69	66	58	35	10

These figures need not be regarded as typical, since the number of sheep was small, the season may have been an unusually severe one, and it is not known that the sheep dealt with were typical New Zealand Romneys. Yet it is probable that some New Zealand Romney sheep can grow wool at varying rates throughout the year. In sheep Nos. 7 and 8 many of the fibres actually ceased growth and were shed. In the other sheep varying numbers of fibres were shed, but the change in rate of growth observed was due to a slowing down in the growth rate of fibres which did not actually cease their growth. Where the rate of growth in length decreased the fibre diameter also decreased to a marked extent. Hence figures for yolk production based on weight of wool would be seriously affected by such changes in rate of growth of wool as have been observed by Waters.

In view of these facts it is evident that the wool fibre is not a completely satisfactory standard by which to measure yolk production in the New Zealand Romney, and it would seem desirable in future to measure absolute yolk production either directly as weight per unit area, or indirectly as yolk content with a measured rate of growth of wool fibre.

That these considerations do not entirely vitiate the present results is shown by the fact that the two fractions of the yolk do not always change in the same direction in a given period, nor to the same extent, as they would do if the apparent fluctuations were merely due to variations in rate of

growth of the wool. As it is generally assumed that these two fractions represent more or less accurately the products of the two types of gland in the sheep's skin, we must conclude that the wax and sweat glands respond differently to certain stimuli.

From Figs. 2 and 3 it is seen that there is a gradual increase in both fractions of the yolk from the commencement of the experiment until shearing, the water soluble fraction increasing to a greater extent than the ether soluble fraction. Evidently this is the phenomenon known by farmers as the "rise" of the yolk in the spring. However, this "rise" is commonly accepted as being of quite sudden occurrence, whereas the increase obtained in this experiment is a gradual one. The explanation which suggests itself is that with the onset of warm weather the yolk become more fluid, flows more readily, and is more easily perceived. Anyone who has examined the fleece of a sheep on a cold day and then on a warm day soon afterwards will be familiar with the marked change in appearance of the yolk. That it is possible for large quantities of yolk to be present without being obvious to the senses, has been found from the analysis of some few samples which were supposed from visual examination to differ widely in yolk content. Samples estimated to yield clean wool differing by 10% have been found to have almost the same yield on analysis.

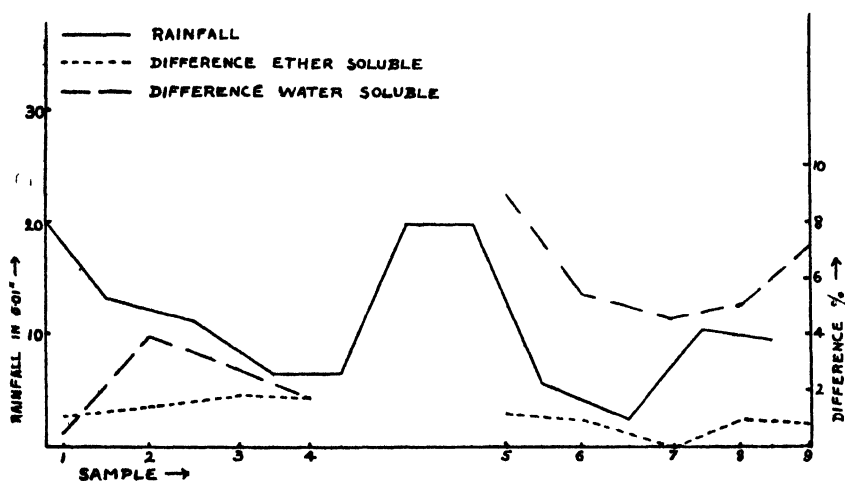


FIG. 4—Showing the average monthly rainfall during the experiment in hundredths of an inch per day, and the difference at each sampling between the covered sheep and the uncovered sheep in average value of (a) ether soluble extract, and (b) water soluble extract.

On the resumption of sampling in January it is found that the values in general for both fractions are lower than at shearing, the differences being more marked in the uncovered sheep. Thereafter for a time, the two fractions pursue different courses; the water soluble fraction increases rapidly to a maximum, and after an interval falls away rapidly to a minimum, and then increases again rapidly. The ether soluble fraction shows a gradual decrease, followed by an increase. This final rapid increase in both fractions occurring

during May, one of the winter months, was entirely unexpected. It may be explained as follows—As stated above, it has been observed by Waters that when the growth rate of the fibre slows up at the beginning of winter some of the fibres are actually shed. In some sheep the majority of the fibres are thus shed during the winter months, although there are always sufficient continuous fibres present to prevent casting of the fleece. Now Duerden and Boyd⁴, working with the Blackhead Persian sheep which sheds its coat annually, found that at the time of shedding of the fleece there was a copious exudation of yolk. Evidently the same factors are still at work in the New Zealand Romney and a tendency to shed the fleece, accompanied by an apparent exudation of yolk, persists to an extent varying with the hereditary make-up of the individual sheep. Shedding of fibres may not take place in all New Zealand Romneys, but perhaps the exudation of yolk occurs even when few or no fibres are actually shed.

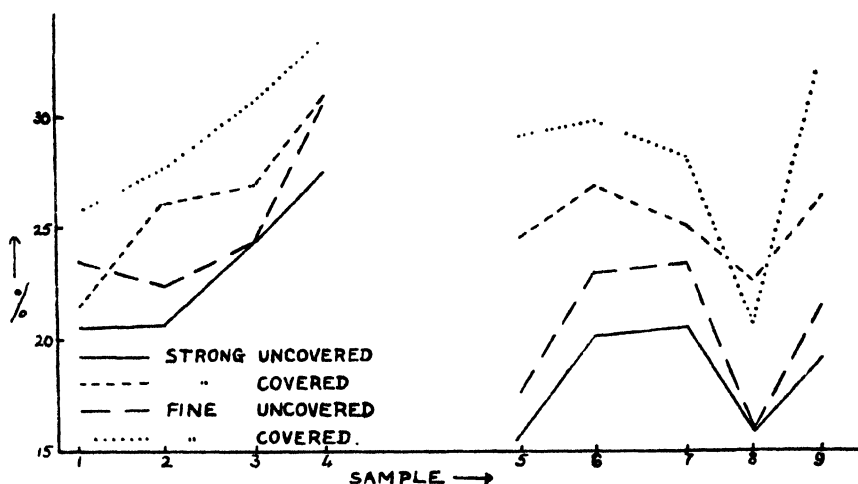


FIG. 5—Showing average values of total yolk at each sampling for each group of sheep (a) strong-woolled uncovered, (b) strong-woolled covered, (c) fine-woolled uncovered, (d) fine-woolled covered.

The effect of covering in preventing leaching is shown in Fig. 4. It is seen that the effect is much more marked on the water soluble fraction than on the ether soluble fraction. It is difficult to see why this should be so if the yolk consists of an emulsion of the wax in the suint. If, on the other hand, as might be expected from the structure of the follicle the yolk consists of two more or less separate layers, firstly a layer of wax on the fibre, secondly a layer of suint superficial to the wax, then it is reasonable to suppose that but little wax would be washed off with the suint. The effect of leaching and its selective nature for the water soluble fraction are much more clearly shown after shearing. Evidently the hogget fleece borne by the sheep prior to shearing acted as an efficient protection under conditions of moderate rainfall, and the effect of the covers was thus masked. From Figs. 2 and 3 the effect of leaching during the first month of the experiment can be seen. There is practically no effect on the ether soluble fraction, but a marked effect on the water soluble fraction.

It has not been possible to trace any correlation, either positive or negative, between the two fractions of the yolk from the results of this experiment.

At the time of the fourth sampling, immediately before shearing, each fleece was carefully examined for various characters, including the appearance of the yolk. Considering the sheep as one group, there was a strong positive relationship between the intensity of the colour of the yolk and the content of water soluble matter. This agrees with the conclusion of Rimington and Stewart,⁵ that the pigment of the yolk is contained in the water soluble fraction.

From the results obtained it appears that the fine-woolled sheep tend to produce a higher proportion of yolk in their fleece. Though the numbers dealt with are not sufficient to give at all times of the year a statistically significant difference in yolk content between the two wool types, the indications are such as to render it probable that larger numbers would give such a difference.

SUMMARY

An experiment is described in which the ether soluble and water soluble fractions of the yolk were estimated in the wool of 40 New Zealand Romney sheep at approximately monthly intervals for a year. Seasonal changes in the amount of these two fractions present have been shown. A sudden and marked increase in the quantity of yolk was found at the beginning of winter.

Half the sheep were covered in order to determine the effect of leaching by rain. It was found that the water soluble fraction was removed to a greater extent than the ether soluble fraction.

The sheep were chosen to show two types of wool, a fine wool and a stronger wool. The results suggest that there is a tendency for the finer wool to be accompanied by a higher proportion of yolk.

Acknowledgments

The author wishes to express his thanks to members of the staff of the Massey Agricultural College for their interest and assistance in this work, and especially to Mr. R. Waters for permission to use some of his unpublished material. Dr. J. T. Campbell, of Edinburgh, has very kindly consented to read the proofs.

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33—A NEW AUTOGRAPHIC LOAD-EXTENSION RECORDER

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ABSTRACT

A method is described of obtaining load-extension diagrams of textile yarns and fibres with constant rate of loading throughout each test, and giving diagrams in rectangular co-ordinates. The novel point in the method consists in the application of the load through a spiral spring by the rotation of a torsion-head at constant speed. Two instruments are described—one for threads of strength between 50 and 500 grams, and the other for filaments and hairs of strength below 20 grams.

INTRODUCTION

When a perfectly elastic material extends under a load the equilibrium extension is reached instantaneously, so that the load-extension diagram is independent of the time taken to trace it. The extension of a plastic material, on the other hand, is dependent on the duration of application of the load, and theoretically the final extension is reached only after an infinite time. Practically, of course, a close approximation to the final extension can be obtained in a finite time, but even the approximate elimination of the time factor in this way would make the production of a load-extension diagram a lengthy process if the elastic imperfection of the material were appreciable.

The comparison of the elastic properties of various materials by the elimination of the time factor is then possible but tedious. More information can be obtained in a shorter time by controlling and, if desired, varying the time factor during the production of the diagrams.

Textiles in general, and rayons in particular, are substances of considerable plasticity, and an appreciable time factor necessarily enters into any consideration of their behaviour under load. A knowledge of the elastic properties of rayon is, however, of great interest to both scientist and technologist, and it is frequently necessary to produce load-extension diagrams in considerable number. But owing to the impossibility of rapidly producing diagrams in which it is eliminated, the time factor must be controlled, so that the load-extension diagram becomes, in effect, a load-extension-time diagram. It is impracticable, however, to record autographically in three dimensions, and it is therefore necessary to arrange that time shall be proportional either to load or to extension, so that the axis of either load or extension may serve also as the axis of time. This means that either the rate of loading or the rate of extension must be kept constant.

The majority of tensile strength and extensibility testing machines are of the pendulum type, and have a constant speed of fall of the lower grip. Most of these can be adapted to give some sort of load-extension record, but cannot easily be adapted to give a load-extension-time record. In this type of machine neither the rate of loading nor the rate of extension is constant throughout any test (unless the material follows Hooke's Law). The time taken to reach any value of load and extension can be calculated from the dimensions of the machine and the speed of fall of the lower grip. But the time thus measured is dependent on the very "elastic" properties that are under investigation.

For example, in the testing of a Lilienfeld viscose and an acetate rayon yarn on a machine of this type with test pieces of equal length and the same speed of fall of the lower grip, the actual conditions of test are by no means equal. Lilienfeld yarn has a high tensile strength and a low extensibility,

whereas acetate yarn has a much lower tensile strength and a much higher extensibility. The Lilienfeld yarn is therefore loaded more rapidly than the acetate—it may be five or six times more rapidly—and the yarns are therefore tested not under similar loading conditions, but under conditions that favour the registration of a high breaking load for the Lilienfeld yarn and a low one for the acetate.

It is, of course, impossible to have the rate of loading and the rate of extension constant in the same test, for this constrains the material to follow Hooke's Law. The diagrams of a thread broken under constant rate of loading and constant rate of extension will be slightly different, even if the total time of rupture is the same. One of these bases must be adopted as standard in comparing load-extension diagrams and the two instruments described in this *Memoir* give a very nearly constant rate of loading.

Existing Load-Extension Recorders

Very few of the existing load-extension recording machines give either a constant rate of loading or a constant rate of extension. The Baer, Goodbrand, and Schopper firms make machines of the pendulum type which work under a constant speed of fall of the lower grip. Alt,¹ however, realised the necessity of working under a constant rate of loading, and so devised an adaptation of the Schopper machine whereby the observer by turning a micrometer screw, adjusts the flow of liquid to the hydraulically operated machine. The screw is adjusted to keep a pointer opposite a line on a revolving drum; the pointer is attached to the pendulum arm, and when the pointer is exactly opposite the line on the drum the pendulum is being moved at a constant rate, that is, the load is being applied at a constant rate. The pendulum type of machine is not suitable for fine work such as the testing of single filaments of rayon or single cotton hairs.

The instruments that depend on the deflection of a spring to give the load, such as those designed by Shorter and Hall,⁶ Lonsdale,⁴ and Polanyi,⁵ can easily be adapted to give a very nearly constant rate of extension by using a strong spring with a large optical magnification of its deflection. The lower grip descends at constant speed, and since the motion of the top grip is made negligibly small the rate of extension is approximately constant.

Instruments in which the thread or hair is held between a grip suspended from one arm of a balance beam and a fixed grip vertically below this, are readily made to give a constant rate of loading. The load is applied by running liquid at a constant rate into a vessel hung from the other arm of the balance beam, as in the Krais³ instrument, by progressing a rider along the balance beam at constant speed, as in the Richard⁷ instrument, or by electromagnetic loading, as in the Earratt² instrument.

The application of the load by means of torsion, as in the instruments to be described, appears to be novel, and certainly lends itself readily to the construction of an instrument with effectively constant rate of loading.

THE NEW TORSION-LOAD INSTRUMENTS

Principle of the Instruments

If a wire or spiral spring is twisted at one end (the torsion head), the couple exerted at the other end (hereafter called the arm end), is proportional to the angle through which the torsion head is twisted. If an arm, free to rotate in a bearing and attached to the arm end of the spring, moves through

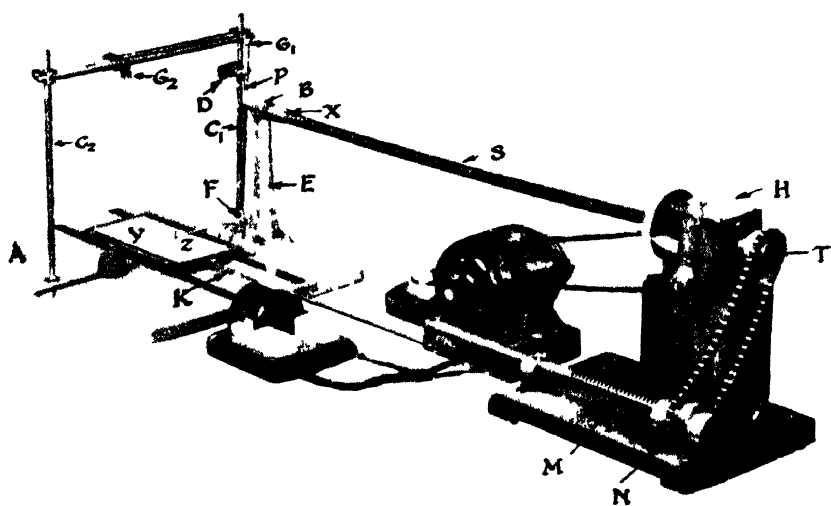


FIG 1

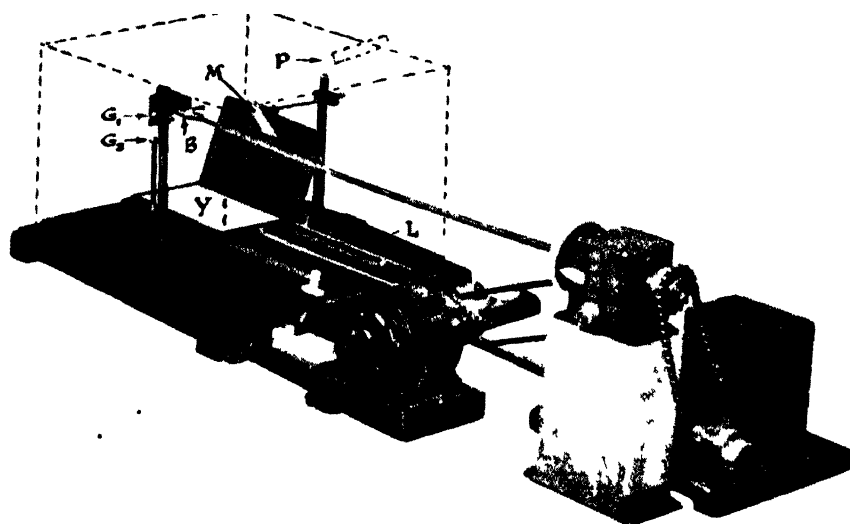


FIG 3

a small angle, say 20° , the couple is not appreciably altered by this movement, provided the angle through which the torsion head is twisted is sufficiently large, so large, in fact, that 20° is a negligible fraction of it. Suppose that the torsion head moves through ten revolutions, or $3,600^\circ$, while the arm moves through 20° , then the error introduced by this motion is only $1/180$ of the total couple. This is the principle that is applied in designing the instruments. The arm, which loads the thread, is not allowed to move through more than 20° , whilst in a normal test the twist at the torsion head is about ten revolutions. The use of a longer and/or weaker spring would make it possible to give the torsion head a much greater angular displacement while producing the same couple, and thus the error due to the movement of the arm could be reduced still further. A spring is used in preference to a wire, for a wire would have to be impracticably long to give the required couple with a reasonable twist at the torsion head.

The extension of the thread or filament is measured by the displacement of the end of the arm, and the load on the thread by the angular displacement of the torsion head. If these two displacements are converted to linear displacements at right angles to each other, it is only necessary to record them continuously and a load-extension curve in rectangular co-ordinates is obtained. Moreover, if the torsion head is twisted at a constant rate, the couple acting on the arm will increase at a constant rate and thus produce a constant rate of loading of the thread.

DESCRIPTION OF INSTRUMENT A FOR THREADS OF STRENGTHS 50–500 GRAMS

The load-extension recorder consists of two parts, the measuring instrument and the mechanism for driving it. (See Fig. 1.)

The measuring instrument consists of a cast-iron base A on which is mounted the pillar E, which supports the double ball-bearing B about 9 inches above the base. In the axle X of the bearing B is fixed the arm P (Fig. 2), which extends the thread. The arm P has at one end the grip G_1 , and at the other end an arm pivoted at F, carrying the pen Z. The distance of the grip G_1 from the axle X is half that from X to F, so that the movement of the pen Z is twice that of the grip G_1 .

If accurate diagrams are to be obtained, the arm P must fulfil the following conditions—

- (1) It must not bend under the load applied by the thread.
- (2) The frictional resistance to its motion must be very small.
- (3) It must have a low moment of inertia.
- (4) It must be very nearly balanced about the axis of the axle X.

In order to comply with these conditions the part *a* (Fig. 2) of the arm is made of $\frac{1}{4}$ -inch aluminium rod, the part *b* of $\frac{1}{8}$ -inch brass tube, and *c* of $\frac{1}{8}$ -inch very light aluminium tube. The pen Z is of glass tube drawn to a fine hole, ground to a sharp point, and buffed to prevent sticking to the paper. In order that the pen shall not press too heavily on the paper and thus cause frictional resistance to the motion of the arm P, it is nearly balanced by a small sliding weight *w*.

The plate Y carries the paper on which the trace is made, and runs on small rollers in grooves parallel to the axle X. Its position can be adjusted relative to the strip K, which has holes drilled in it 1 cm. apart, by pegging it to a suitable hole.

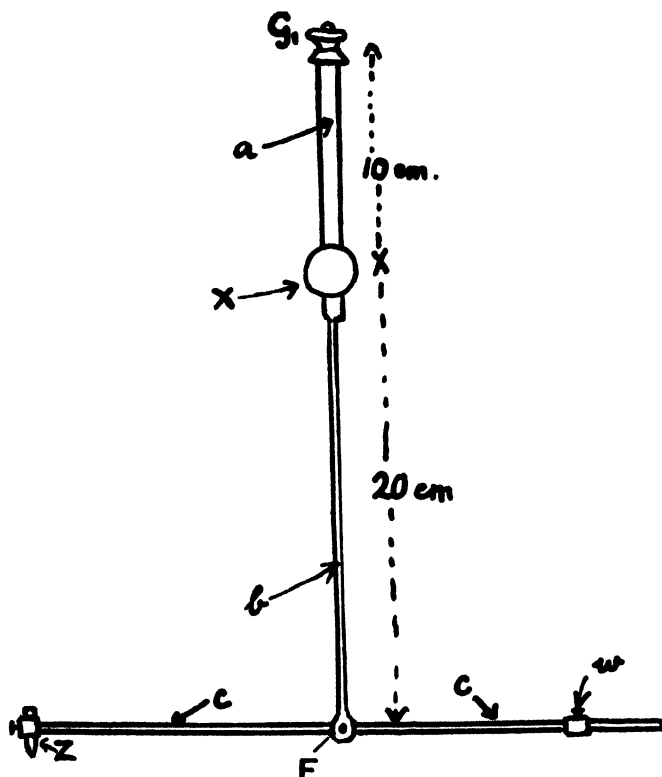


FIG. 2

The fixed grip G_2 is situated horizontally opposite the grip G_1 ; the test length is adjustable by sliding G_2 along two rods held fixed to the pillars C_1, C_2 . The front stop at D fixes the initial position of the arm at about 10° to the vertical, and the back one prevents it from revolving after the thread has broken. The driving mechanism is mounted on a separate wooden base. It consists of an electric motor, which drives the spring S through the 100-1 reduction gear H. From the shaft T is a chain drive to the wheel N, which draws along the threaded rod M; the motion of M is communicated to the strip K so that the plate Y is moved at a rate directly proportional to the twist at T. Mounted on the shaft T is a circular scale on which the twist can be read.

Operation of the Instrument

The spring is adjusted to the zero position, that is, the position in which the arm P is in equilibrium and vertical. The thread is mounted between the grips G_1 and G_2 with just sufficient tension to pull the arm P against the front stop D. The motor is then started and loading begins. As the thread

extends the pen *Z* moves across the paper a distance equal to twice the extension at any instant; at the same time the paper is pulled along so that the distance it moves is proportional to the load on the thread. Thus the load-extension diagram is traced out by the pen. When the thread breaks the pen shoots across the paper, giving a definite end point to the curve.

After each test the motor is reversed until the arm *P* comes back to the zero position. When the plate *Y* has been moved along 1 cm. by adjusting the peg in the strip *K*, the instrument is ready for the next test. Usually, ten diagrams with starting places 1 cm. apart, can be comfortably traced on one paper.

The length tested can be adjusted to give a more or less square diagram without affecting the rate of loading since this is independent of the extension. This is an advantage over a constant rate of extension instrument, where the speed of the driving motor must be proportional to the length of the thread being tested.

The rate of loading can be varied over a very great range by alteration of the motor speed and the gearing of the drive to the shaft *T*.

Calibration and Errors of Instrument

Calibration—A light needle-bearing pulley is substituted for the grip *G*₂. Weights are hung over this pulley and connected by a thin flexible string to *G*₁. The motor is then started and the spring wound up until the hanging weight is just balanced by the torque of the spring, with the arm *P* in the vertical position. The movement of the plate *Y* is recorded and plotted against the load. Table I shows that the plate movement is proportional to the applied load.

Table I
Calibration of Spring 200 coils 0.05 in. wire.
Load in grams = $\cdot 18.6 \times$ Movement of Plate in cm.

Movement of Plate (cm)	Load (Calculated)	Load (Actual)
0	0	0
0.27	5.0	5
0.50	9.3	10
1.03	21.0	20
2.10	39.0	40
5.58	104.0	105
11.12	206.5	205
13.75	255.5	255

Error due to Radial Motion of the Arm—The arm *P* is arranged so that its initial position is inclined at about 10° to the vertical and moves about 10° past the vertical in a normal test. The pull of the thread is perpendicular to the arm *P* only in the vertical position. On a 20-cm. length of thread it can readily be calculated that the inclination of the thread to the horizontal in the initial position (*i.e.* position of maximum error) is about $\frac{1}{2}^\circ$. If a 10-cm. length were broken, this inclination would be about 1° . This means that the pull of the thread is at an angle of $10\frac{1}{2}^\circ$ or 11° to the direction of movement of the grip according as a 20-cm. or 10-cm. length is broken. Hence, if *L* is the load measured by the torque of the spring, the pull on the thread is $L \cos. 10\frac{1}{2}^\circ$ or $0.983 L$, an error of less than 2 per cent.

Error due to Friction of Moving Parts—The static friction of the bearing plus that of the pen can be shown to be less than the equivalent of $\frac{1}{2}$ gram load by noting the amount of twist required to be given to the torsion head

before the pen moves from the zero position. The dynamic friction is always less than the static friction, and though this increases with the load and is not directly proportional to it, the friction is shown to be a negligible quantity by the calibration table.

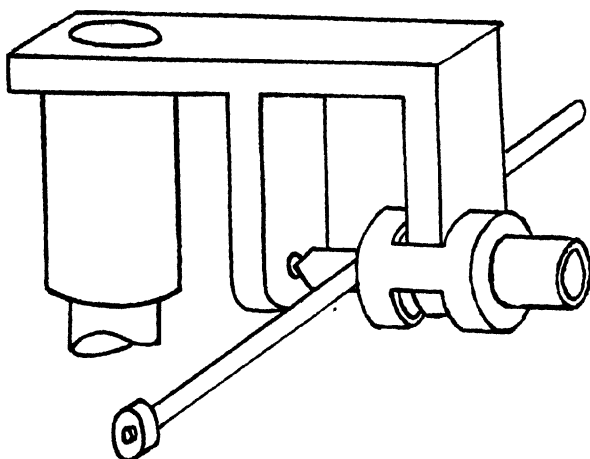


FIG. 4

Error introduced by the Inertia of the Moving Parts—The moment of inertia I of the arm P with its attachments is of the order of 5,000 gm. cm.² The couple produced by a change in angular velocity (ω) of this arm is $I \frac{d\omega}{dt}$ dyne cm. This is equivalent to a force of $\frac{I}{10g} \cdot \frac{d\omega}{dt}$ grams (g =acceleration due to gravity=981 cm. sec.⁻²) at a radius of 10 cm. (the distance of the grip G_1 from the axis of rotation) and this is approximately equal to $0.5 \frac{d\omega}{dt}$ grams. In a viscose or acetate rayon diagram the maximum change in velocity of the arm is from about 0.01 radian per second to 0.10 radian per second at a normal rate of loading. According to the diagram the time taken for this change in velocity is about one second, and even if we assume that this change takes place in one quarter of a second, and at a uniform rate over this period, the error introduced will be $0.5 \times \frac{0.09}{0.25}$ gram = 0.18 gram. If the rate of loading were ten times as great the error would be 1.8 grams. It is seen, therefore, that inertia effects are very small even for comparatively high rates of loading.

DESCRIPTION OF INSTRUMENT B FOR FILAMENTS OF STRENGTHS UP TO 20 GRAMS

The principle of the instrument is exactly the same as that of its heavier counterpart, but the moving parts are much lighter. The recording is done photographically, with the twofold object of reducing the inertia of the

moving parts and producing a greater magnification of the extension, and so making it possible to obtain the desired accuracy with a shorter test length and a much smaller angular movement of the arm.

The cast-iron base is similar to that used in the heavier instrument, but it is covered by a wooden box (shown in Fig. 3 in dotted lines) with a sliding front equipped with a red glass window. The bearing B is a needle bearing drawn on a larger scale in Fig. 4. The grip G_1 is situated vertically above the fixed grip G_2 . The plate Y is fitted with a hinged lightproof lid which can be opened and shut from outside the box by turning the sliding rod L, which has two projections, which fit into two tubes attached to the lid. M is a plane mirror above the plate Y at 45° to the vertical. The trace is made by the image of the illuminated pinhole P, focussed on bromide paper on the plate Y by a small concave galvanometer mirror carried on the axle and reflected from M.

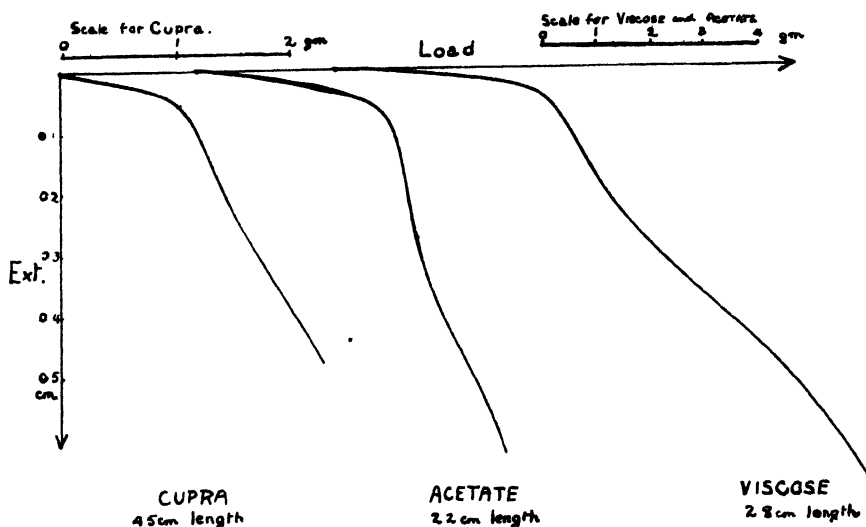


FIG. 5

The drive is exactly the same as in the heavier instrument, except that the drive for the spring and the plate are in different relative positions, since the bearing B is at the front of the instrument to facilitate mounting the filaments in the grips.

Operation of Single Filament Tester

Mounting of Filaments—It is essential that the filaments should be mounted to give a definite test length, with only just sufficient tension to keep them taut. It is possible to do this with fairly coarse filaments in the usual way, as on a thread tester, but this method is impracticable for very fine filaments such as those of cuprammonium or Lilienfeld rayon; the procedure outlined below is therefore followed.

The threads are cemented with shellac across a slit of the required width in a piece of paper. The paper is mounted between the grips and the tautness of the filament carefully adjusted with the paper still in position; the paper is then cut away leaving the filament ready to be loaded.

Loading the Filament—The plate Y is filled with bromide paper in a dark room and put into position with the lid closed. When the filament has been mounted, the front of the box is closed, the lid of the plate Y raised, and the motor is switched on. The spot of light can be seen travelling across the paper through the red glass window. When the filament breaks the motor is stopped, and the lid of the travelling plate closed. The motor is then reversed and the plate wound back to its zero position; it is moved 1 cm. along by putting the peg in the next hole of the drilled strip which draws it along, and the instrument is then ready for the next test. Typical diagrams are shown in Fig. 5.

Calibration and Errors of the Single Filament Tester

Calibration—The calibration is effected by hanging weights directly from the grip G_1 and balancing them by the twist in the spring. Table II shows that the plate movement is proportional to the applied load.

Table II
Calibration of Light Spring for Single Filaments.
Load in grams = 0.795 × Movement of Plate in cm.

Movement of Plate (cm.)	Load (Calculated)	Load (Actual)
0	0	0
0.09	0.071	0.065
0.21	0.167	0.165
0.34	0.270	0.265
0.72	0.572	0.565
1.34	1.065	1.065
2.58	2.050	2.065
6.35	5.050	5.065
12.63	10.050	10.065

Error due to Radial Motion of Arm—This has been reduced to a maximum of about 0.2%, since the total angle through which the arm rotates is only about 8°.

Error due to Friction—The static friction can be shown to be less than 0.0004 gram.

Inertia Effect—The moment of inertia of the arm and its moving attachments is only about 200 gm. cm.², and since it moves much more slowly than in the heavier instrument the maximum possible error due to inertia is about 0.003 gram at a normal rate of loading.

FURTHER USES OF THE INSTRUMENTS

Other applications of these instruments suggest themselves—

(1) Load-Extension Diagrams of Yarns or Filaments Immersed in a Fluid

By the attachment of a light chain to the moving grip (passing over a pulley if necessary) the specimen to be tested can be immersed in a vertical position in a liquid (see Fig. 6). It is convenient to mount the tube to hold

the liquid on a rubber bung on the fixed grip. This can be seen in front of the moving plate Y in Fig. 1.

(2) Hysteresis or Repeated Loading and Unloading Diagrams

The loading of a yarn or filament can be discontinued at any point short of rupture, and the load may be partly or wholly removed immediately or after a lapse of time; this may be repeated as often as desired. A typical trace for a rayon filament is reproduced in Fig. 7.

(3) Extension-Time Diagrams at Constant Load

By disconnecting the drive for the torsion head from the drive for the record and arranging to drive the record at a known speed along the load axis, it is possible to apply a constant load to the test piece and obtain a time-extension record in rectangular co-ordinates.

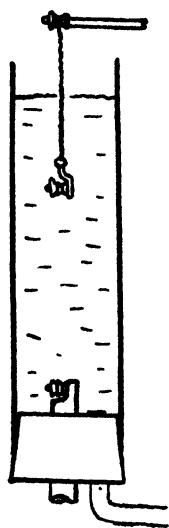


FIG. 6

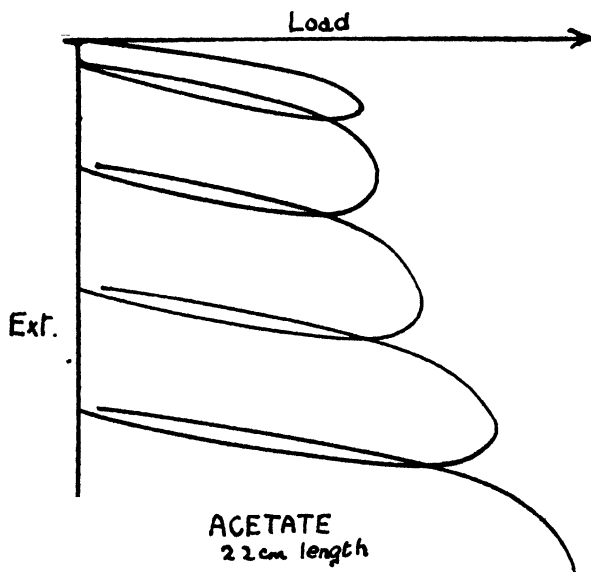


FIG. 7

(4) Shrinkage-Load Diagrams

The apparatus for the production of load-extension diagrams of filaments immersed in liquid is used. The torsion head is wound up to a tension well above the shrinking force of the yarn, which is then fixed just taut between the grips, which are as wide apart as the stops allow. The glass tube is then filled with the shrinking liquid and the spring is unloaded by starting the motor in the reverse direction. When the shrinking force of the yarn is large enough to overcome the torque of the spring, the spot of light moves across the paper, the distance always being proportional to the shrinkage of the

yarn, whilst the load on the yarn is determined by the position of the plate, which moves perpendicularly to the direction of movement of the spot of light. Thus a shrinkage-load diagram in rectangular co-ordinates is traced out.

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TRANSACTIONS

34—INVESTIGATIONS ON FABRIC SEAMS

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Most textile fabrics require to be cut into segments to render them adaptable for articles of clothing and this process is variously known as stitching, seaming, or joining. In the knitted fabric section of the industry, these operations are particularly important as they involve the joining of selvaged fabric as well as that cut from knitted material which is liable to curl at the edges, and which has a considerable reserve of elasticity or stretch. It is important to ascertain the relative merits of different types of seaming or joining. The present investigations have been undertaken to define the properties of the chief systems of joining textile fabrics, and make comparisons of their relative merits as regards durability, firmness, and stretch. These properties are all-important in jointures, for if these fail to withstand the diverse thrusts and strains to which they are subjected during wear, the life of the garment may be considerably curtailed. This is particularly the case in knitted material employed for outer wear where the style of join influences greatly the degree of comfort experienced by the wearer. It is also useful to devise a method of ascertaining whether the various members of a seam are correctly balanced in the stitch, and to ascertain the resultant strength of any set of threads combining to form a fabric join. Another factor of importance is the ascertainment of the amount of thread consumed in making the join, as this has an important bearing on cost, enormous quantities of high-grade sewing cottons and seaming yarns being employed in these operations.

The investigations which follow have been conducted throughout on the basis of plain knitted fabric worked in single 8's cotton counts on a circular knitting machine, having eight feeders in the circumference. The fabric when finished has a thickness of .026 inch as measured by roller calipers. The seaming of the test pieces was performed on standard types of sewing and seaming machines employed in the industry. To ascertain the strength and stretch of seams, the test lengths were executed across the fabric in the courses direction, and the fabric was cut $\frac{7}{8}$ inch on each side of the line of seaming. The result of this method is to take advantage of the excessive elasticity of the knitted fabric in the direction of the width, so that the strain comes on to the seam and its breaking point is reached, with the fabric still a long way from its limit of elongation and point of fracture. The registered strengths of the seams show, in most cases, a proportion which can be traced to the influence of the fabric, but a method of making a correction for this is detailed. The materials employed in the tests were 3/60's cotton of the standard sewing types throughout, except for the nine-thread seam which required a single thread of 18's cotton, in certain of its elements.



Fig 1.



Fig 5



Fig 6

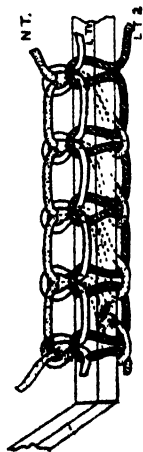


Fig 19.

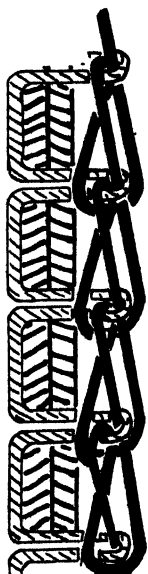


Fig 11.

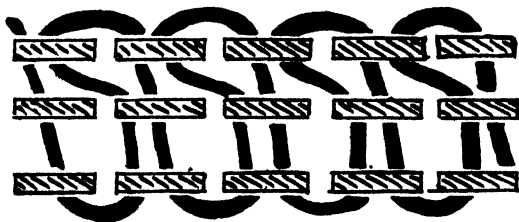


Fig 12.



Fig 16.

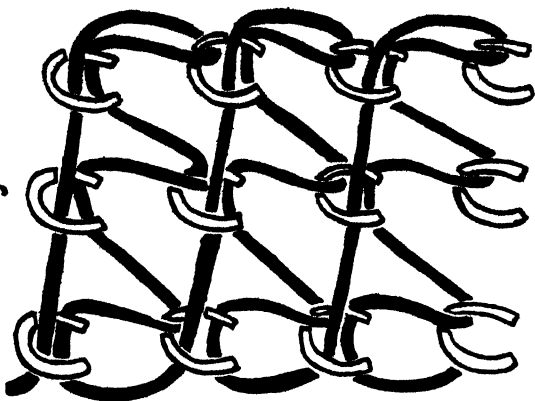


Fig 13.

These threads were fairly uniform with each other, the breaking load varying between 1.2 lb. and 1.5 lb. in the types used. Before testing, all the materials were placed for at least 24 hours in a humidity control chamber regulated for 65% of relative humidity at a temperature of 70 degrees. Test lengths in general were taken as 6½ inches and Goodbrand's vertical cloth testing machine was employed, with the lower jaw travelling at a speed of 18 inches per minute, the machine being operated automatically by electric power.

During the making of the test pieces, the amount of thread required for a standard length of seam was carefully measured by marking the thread previously at each 12 inches. These marks are easily traced in the completed seam, so that the number of feet of yarn required per foot or yard of seaming is readily ascertained. For convenience this factor is given as a figure, thus a take-up of 4.2 means that 4.2 feet of yarn are required to produce 1 foot of seam; 4.2 yards of thread are required for 1 yard of seam and so on.

The next item of importance in this work is the number of stitches inserted per inch, in certain types of machines such as the chainstitch, the compass extends from four to 30 stitches per inch, but in other machines the range is more restricted. Usually stitches per inch are related to the thickness of fabric, coarser fabrics requiring fewer stitches per inch as compared with finer textures. In these tests, however, the fabric used is identical throughout.

The simplest form of seaming stitch is given diagrammatically in Fig. 1, this being known as the chain stitch. It is shown uniting two plies of fabric, the upper portion of the seam has the thread in single form extended from one stitch to another, and underneath the fabric, the thread is seen to be double and with one stitch drawn through another in the form of chains. The take-up of thread is determined by the following factors, the length of stitch L , the thickness T consisting of two plies, and the thread goes through twice at each stitch. The next factor is the portion which stretches double under the fabric so that the take-up of thread U can be stated as follows—

$$\frac{3L+2T}{L}=U$$

Let there be 18 stitches per inch, then the length L will be 1/18 inch = 0.055. Given that the take-up is 4.5, which is a common figure for this type of seam, thickness actually sewn may be calculated approximately as follows, for in sewing there is considerable pressure exerted by the presser foot of the machine.

$$\begin{aligned}\frac{3L+2T}{L} &= 4.5 \\ 3L+2T &= 4.5L \\ 2T &= 1.5L \\ 2T &= 1.5 (0.055) = 0.075 \\ T &= 0.0375 \text{ inch}\end{aligned}$$

This gives the thickness of fabric as sewn, the fabric normally is .028 inch in thickness, and there are two plies, so that the total thickness is given by .056; the difference between those two represents the reduction of thickness due to pressure which is .056—0.0375 = 0.0185 inch.

Altering the stitch setting to ten stitches per inch will give a stitch length L of $\cdot 1$ and taking the thickness as $\cdot 0375$, the take-up U may be calculated as follows from the formula—

$$\frac{3(\cdot 1) + 2(\cdot 0375)}{\cdot 1} = \frac{\cdot 3 + \cdot 075}{\cdot 1} = \frac{\cdot 375}{\cdot 1} = 3\cdot 75 \text{ as the take-up.}$$

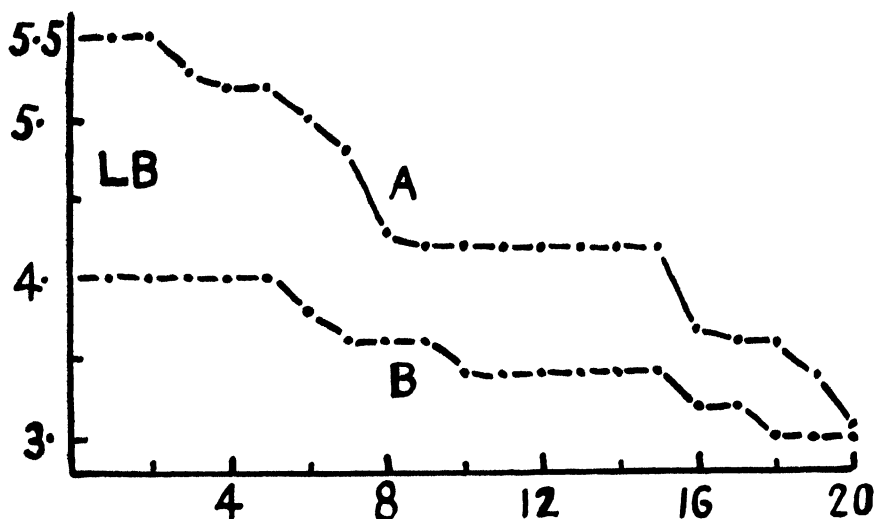


FIG. 2

The following two tables give the results of a series of tests made on the vertical cloth tester under the conditions just mentioned, where the breaking load is stated in lb. and the extension in inches. Twenty tests were made on each sample, 3/60's cotton of reverse twist being employed in the needle.

Chain Stitch—10 Stitches per inch Take-up of Thread = 4.52			Chain Stitch—12 Stitches per inch Take-up of Thread = 4.4		
(1)	Breaking Load	Extension	(2)	Breaking Load	Extension
1	5.0 lb.	4.25 in.	1	4.4 lb.	3.62 in.
2	4.4	4.37	2	4.2	3.5
3	5.2	4.75	3	3.8	3.75
4	5.2	4.25	4	4.0	3.5
5	5.5	4.25	5	4.0	3.75
6	3.7	4.75	6	4.4	3.5
7	4.3	4.5	7	4.0	3.5
8	4.3	4.0	8	3.8	3.37
9	5.5	4.75	9	4.2	3.62
10	4.3	4.37	10	4.2	3.62
11	4.3	4.62	11	3.2	3.37
12	4.8	5.0	12	4.0	3.37
13	3.6	4.25	13	4.4	3.62
14	4.3	4.0	14	4.2	3.5
15	5.3	4.5	15	4.0	3.5
16	3.4	4.25	16	4.0	3.62
17	4.3	5.12	17	4.4	3.5
18	3.6	4.5	18	3.8	3.37
19	4.3	4.67	19	3.0	3.62
20	3.1	4.5	20	4.4	3.25
Mean	4.42 lb.	4.48 in.	Mean	4.02 lb.	3.52 in.

This method was extended over a range of 10, 12, 14, 18, and 22 stitches per inch, of which the two extremes are shown in plain graphical form in Fig. 2 where the upper line A shows the results of 20 tests in descending order of value, on the ten stitches per inch seam with a mean of 4.42 lb. breaking load, as detailed above at (1), and the lower graph B, which has a mean of 3.52 lb. The corresponding curves for elongation are given in Fig. 3, where

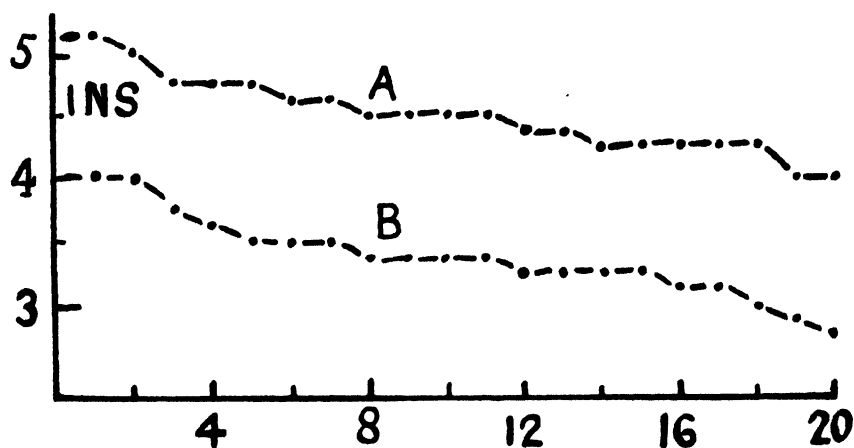


FIG. 3

the upper curve A gives the results of 20 tests at ten stitches per inch with a mean of 4.48 inches, and the lower graph B gives the results for 22 stitches per inch, which have a mean of 3.52 inches elongation, all taken on the $6\frac{1}{2}$ inch test length. Fig. 4 shows the results of the mean of all five tests from 10 to

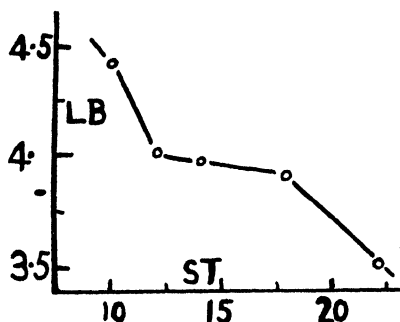


FIG. 4

22 stitches per inch where the breaking load which can be borne is seen to diminish as the number of stitches per inch increase, there being apparently a kind of medium area where the difference is very slight, but a marked reduction from 10 to 12 stitches per inch and when the highest number of

stitches per inch are approached. As the grip of the chains becomes tighter, the thread is unable to bear so much strain and the material easily cuts as it intersects upon itself.

The Lockstitch Seam

This type is widely employed for joining all classes of woven fabrics and is the principle adopted in the domestic sewing machine. In the knitting industry it is chiefly used for attaching pieces of woven fabric to knitted material and it is a method which gives very rigid results, the join is firm and strong and cannot easily be unpicked, but lacks that elasticity which one requires for joining knitted materials. A diagram illustrating the structure of this seam is given in Fig. 5, where the upper thread in black represents the thread inserted by the needle, whilst the lower thread with which it locks, issues from a shuttle under the fabric. The two threads unite in the centre of the material in a locking action, when both threads take an equal share of the strain. It often happens, however, that the two threads are not fed into the material with an equal amount of tension so that one thread occurs at a greater length than its neighbour, giving an unbalanced form of join which causes the strain to fall predominantly on one of the threads, with consequent weakening of the join. This condition is illustrated in Fig. 6, where the upper needle thread has been fed at too slack a tension, whilst the lower shuttle thread is too tight, so that the appearance of the stitching on the lower side is spoiled and the strength of seam considerably impaired. Following Fig. 5, the elements in the take-up of this seam may be noted along with a method of estimating the contraction of thickness due to the action of the presser foot and more particularly of the two yarns as they tightly interlock with each other. Let the set of the stitching be 18 per inch as before, with a total take-up of 2.6, which gives 1.3 for the upper thread and a similar amount for the lower thread. The main factors in take-up will be twice the stitch length plus twice the thickness of the fabric as shown in Fig. 5, neglecting any take-up which may be due to the locking of the threads in the centre.

$$\frac{2L+2T}{L}=2.6$$

The stitch length is .05 as before, so that—

$$\begin{aligned} 2L+2T &= 2.6L \\ 2T &= .6L = .6 (.05) = .03 \text{ inch} \\ 2T &= .03 \therefore \text{Thickness} = .015 \text{ inch} \end{aligned}$$

But the normal thickness was given as .056 so that .056—0.015=.041 inch, which represents the diminution in the thickness of the material due to the factors stated.

This point of the unbalanced seam is of such practical importance that for comparative purposes a seam (A) was first worked perfectly balanced with the two threads locking in the centre and then worked slightly unbalanced at (B), so that one of the threads was tighter in the stitch than the other. The accompanying tables (A) and (B) give details of a series of 20 tests made on them by the single thread testing machine where the results are recorded in ounces and inches elongation on a 12 inch test length.

(A) Breaking Load			Elongation	(B) Breaking Load			Elongation
50 oz.	...		2.87 in.	38 oz.	...		2.37 in.
46 "	...		1.75 "	33 "	...		1.62 "
48 "	...		2.12 "	37 "	...		1.62 "
43 "	...		2.12 "	36 "	...		1.62 "
47 "	...		3.12 "	44 "	...		2.37 "
43 "	...		2.37 "	41 "	...		2.00 "
43 "	...		2.25 "	39 "	...		1.5 "
45 "	...		2.0 "	36 "	...		1.62 "
44 "	...		2.12 "	40 "	...		2.00 "
42 "	...		2.62 "	41 "	...		2.00 "
46 "	...		2.37 "	39 "	...		1.62 "
44 "	...		2.0 "	43 "	...		2.12 "
42 "	...		2.25 "	38 "	...		1.62 "
42 "	...		1.87 "	42 "	...		1.75 "
44 "	...		2.12 "	41 "	...		2.0 "
42 "	...		1.5 "	46 "	...		2.75 "
42 "	...		2.0 "	44 "	...		2.12 "
43 "	...		2.0 "	42 "	...		2.37 "
40 "	...		2.12 "	41 "	...		1.75 "
42 "	...		1.62 "	44 "	...		2.25 "
Mean = 43.9 oz.			2.19 in.	Mean = 40.3 oz.			1.95 in.

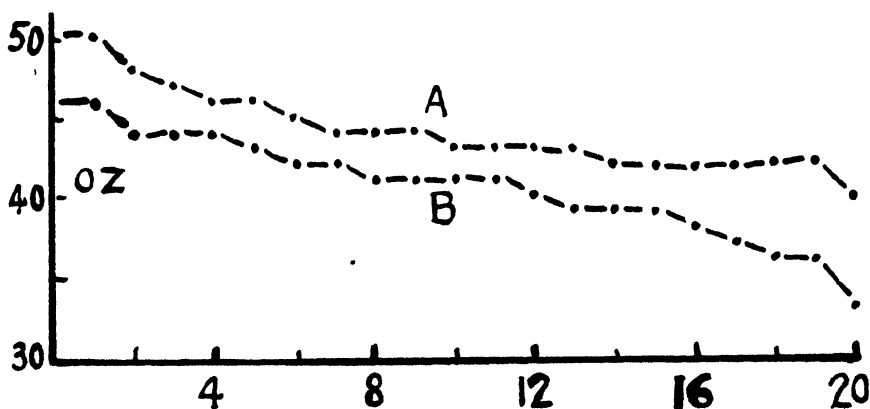


FIG. 7

These have been drawn out in graph form for comparison purposes in Fig. 7 where the graph A corresponds to the balanced seam and B the unbalanced. The take-up of thread in a series of tests made on the lockstitch machine at varying numbers of stitches per inch gave the following results on the standard cotton knitted fabric—

12 stitches per inch,	total take-up of 2.66
14 "	" " " " 2.74
18 "	" " " " 2.90
22 "	" " " " 2.96

The mean breaking loads and elongations of 20 tests pieces are given here-with—

12 stitches per inch,	43.9 oz.	2.19 in.
14 "	43.1 "	2.55 "
18 "	41.8 "	3.5 "
22 "	38.0 "	1.97 "

These results for breaking loads are given in Fig. 8. To illustrate the difference in strength and elongation of these two varieties of seam, two series of lengths were made on the chainstitch and the lockstitch, both having

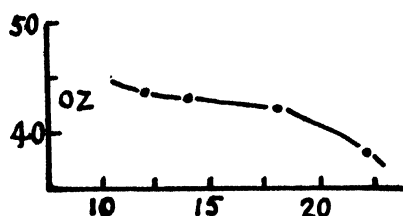


FIG. 8

18 stitches per inch and tested on the cloth testing machine as before. The results of those comparisons are given graphically in Fig. 9 where the upper curve represents the values obtained from 20 tests of the chainstitch, whilst the lower curve gives a similar series of results made on the lockstitch. The

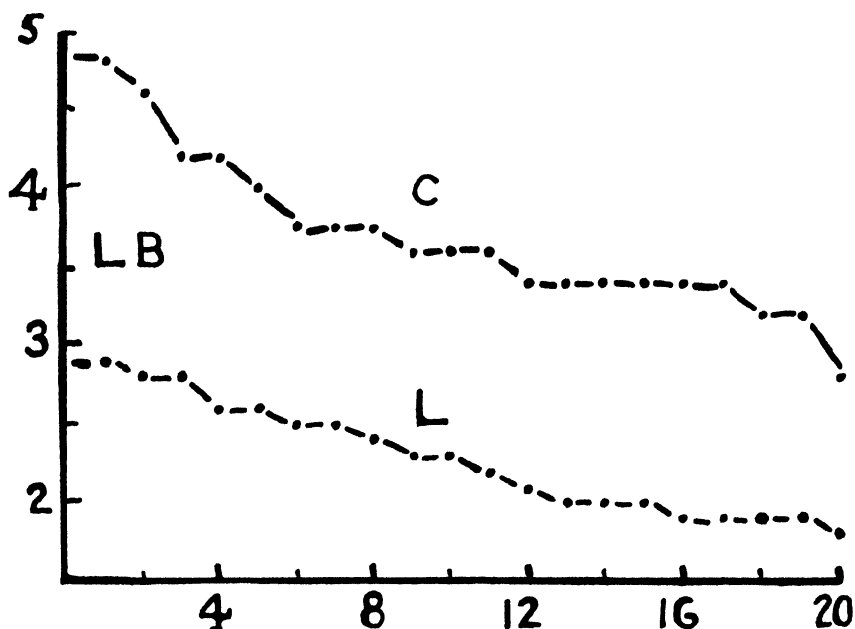


FIG. 9

difference in breaking load between the two seams is most emphatic and indicates the reason for the strong preference of the derivatives of the chainstitch seam, such as the overedge chainstitch, as a most satisfactory method of joining selvedged knitted fabrics. It also shows the entire unsuitability of the lockstitch for this purpose. The strain at once comes on to the individual seaming threads in the case of the latter, whilst the chainstitch, owing to the greater amount of internal yield amongst its chains, yields with the knitted fabric itself and gives much better results in use. The corresponding results for elongation are given in Fig. 10.

It is of practical interest to calculate the cost of using any particular arrangement of threads in a seam or join and thereby to compare the relative costs of different systems of conducting the joining operation. A convenient method of doing this is to quote the cost as pence per 1,000 yards of seaming. The items required for the operation are the counts of the sewing threads and the cost of this per lb. along with the take-up figure for each thread of the seam.

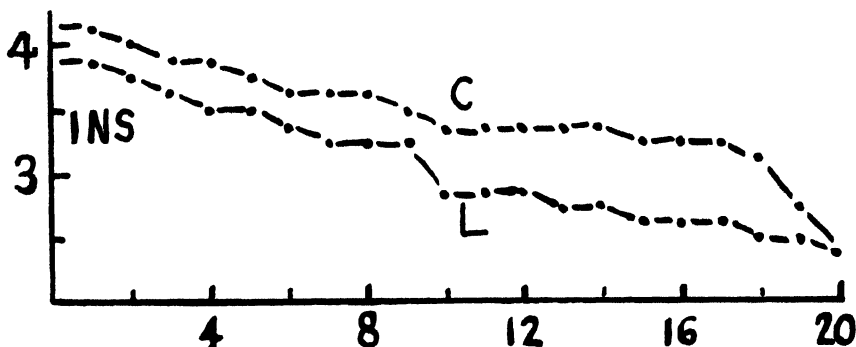


FIG. 10

Let Y represent the number of yards per lb. of the given yarn, with D as the cost in pence per lb., then the number of yards obtained for 1d. is stated thus—

$$\frac{Y}{D} = \text{yards per penny.}$$

With U as the take-up figure and 1,000 yards as the unit length, the total length of thread consumed is 1,000 U and the cost in pence for this is given by

$$1,000U \div \frac{Y}{D}$$

$$* \frac{1,000UD}{Y} = P \text{ the cost per 1,000 yards of seam.}$$

Take as example a chainstitch seam with a take-up of 3.5, then the cost per 1,000 yards of seam is obtained thus—

$$\frac{1,000 \times 3.5 \times 72}{16,800} = 15d.$$

All cases arising at this count and price in the chainstitch will have the following common factors—

$$\frac{1,000 \times 72}{16,800} = \frac{30}{7} = K$$

* To illustrate the use of this formula, let 3/60's be the count of the yarn and its cost 72d. per lb. For this system of yarn counts there are $20 \times 840 = 16,800$ yards per lb., so that the cost in yards per penny is $16,800 \div 72 = \text{yards per penny.}$

so that the cost per 1,000 yards of seam will be obtained by UK where U is the take-up figure and $K=30/7$. Thus to find the cost of a seam with a take-up of 4.14—

$$\frac{30}{7} \times 4.14 = 17.7 \text{ pence per 1,000 yards.}$$

24's worsted count is often employed as a seaming thread and if the price of this is 48d. per lb., then the corresponding value of K for this example will be obtained thus—

$$\frac{1,000 \times 48}{24 \times 560} = \frac{25}{7} = K$$

If 350 denier rayon yarn is also employed, then $5,315 \div 350 = 15.2$ equivalent cotton count. Let the cost of this be 56d. per lb., when the relative constant will be derived as follows—

$$\frac{1,000 \times 56}{15.2 \times 840} = 4.4 = K$$

Double Chainstitch

This style of jointure may be said to merge the properties of the chainstitch and the lockstitch, it is less rigid than the lockstitch but firmer than the chainstitch and does not show the same facility for unroving when broken. A diagram of the two-thread double chainstitch, sometimes known as the double-lock chainstitch, is given in Fig. 11. The shaded portion above represents the thread which come from the needle, whilst the dark thread is supplied by the looper placed under the fabric. The action of the needle is to ram the thread through the two layers of fabric shown, so that the thread appears double at each stitch. Tracing the intersection of the needle thread it will be observed that this is approximately equivalent to one length of stitch, plus two thicknesses of fabric, to which must be added a constant to account for the marked intersection of the two threads on the underside of the fabric. These relations may be stated thus for a practical take-up of 2.8 at nine stitches per inch—

$$\frac{L+2T}{L} + K = 2.8$$

Stitch length is $1/9$ inch = .111, and the thickness of the fabric is .056, $2T = .112$, so that the value of K is found as follows—

$$\begin{aligned} \frac{.111 + .112}{.111} + K &= 2.8 \\ \frac{.223}{.111} + K &= 2.8 \end{aligned}$$

$$2 + K = 2.8 \text{ therefore } K = .8$$

Considering the looper thread, having a take-up ascertained practically, as 3.4, the factors approximately are three lengths of the stitch plus a constant allowed for intersection—

$$\begin{aligned} \frac{3L}{L} + K &= 3.4 \\ 3 + K &= 3.4 \\ K &= .4 \end{aligned}$$

The following gives details of 20 tests made under the usual conditions on the cloth-testing machine for this seam with 3/60's sewing cotton, balanced.

(A) Take-up of needle thread = 2.8
Take-up of looper thread = 3.5

Total = 6.3

Also for comparison are given the results of a seam unbalanced by drawing the needle thread tight in relation to the looper thread thus—

(B) Take-up of needle thread = 1.25
Take-up of looper thread = 5.00

Total = 6.25

(A) Breaking Load		Elongation	(B) Breaking Load		Elongation
2.7 lb.	...	2.25 in.	1.0 lb.	...	1.37 in.
2.5 "	...	2.5 "	1.5 "	...	1.25 "
4.0 "	...	2.5 "	1.4 "	...	0.87 "
2.5 "	...	2.5 "	0.9 "	...	1.00 "
3.2 "	...	2.25 "	1.1 "	...	1.37 "
3.0 "	...	2.5 "	0.7 "	...	1.00 "
2.5 "	...	2.25 "	2.2 "	...	1.75 "
3.0 "	...	2.62 "	1.8 "	...	1.25 "
3.2 "	...	2.12 "	1.3 "	...	1.00 "
3.2 "	...	2.25 "	1.3 "	...	1.37 "
2.8 "	...	2.00 "	2.1 "	...	1.87 "
2.8 "	...	2.37 "	1.1 "	...	0.87 "
2.9 "	...	2.37 "	1.3 "	...	1.5 "
3.1 "	...	2.25 "	1.3 "	...	1.12 "
3.2 "	...	2.37 "	1.2 "	...	1.62 "
3.4 "	...	2.12 "	0.9 "	...	0.75 "
3.3 "	...	2.37 "	1.7 "	...	1.25 "
3.3 "	...	2.5 "	1.3 "	...	1.5 "
4.0 "	...	2.0 "	1.1 "	...	1.25 "
3.6 "	...	2.62 "	1.2 "	...	1.12 "
<u>Mean = 3.11 lb.</u>		<u>2.3 in.</u>	<u>Mean = 1.32 lb.</u>		<u>1.25 in.</u>

The difference between the strengths of those two seams balanced and not balanced shows the practical importance in having the constituent threads properly adjusted in relation to each other, so that the strain will be borne by both threads equally and not by a single thread, as is evident in tests (B), where the needle thread is so tight that it is broken quite early in the test and the strength of this seam is simply the strength of the needle thread.

A remarkable feature of this type of seam is the way in which it can be extended in scope by the addition of other needle threads which can all be used along with the single looper, thus a second needle can be added to give a two-line stitch, or the three-thread double chainstitch, and a third needle gives a four-thread seam. On top of these can be added what is known as a covering thread which moves backwards and forwards across the seam or join and obscures the rawness caused by the overlapping of two cut edges of knitted fabric. This is known as the five-thread seam and the face diagram is given in Fig. 12 where the three-needle threads may be noted as the vertically arranged segments appearing on the face. Working underneath them and moving from side-to-side is the covering thread in black, the addition of which not only improves the appearance but also gives greater strength to the jointure. A view of this seam on the back is given in Fig. 13, where the three needle threads are shown in section, with the convolutions

of the looper thread clearly marked in black. This system renders it important that the looper thread should be correctly balanced in the seam, for if this breaks, all support for the other threads is withdrawn. An analysis of the seam may be attempted from the diagrams given at Fig. 12 for the take-up of the covering thread, which in the example quoted is 4.6. In this case a new factor comes to be considered, the distance between the needle threads as they lie side by side in the fabric. In this case the distance is .125 inch, but owing to the way in which the looper thread draws the needle threads together by its side-to-side movement, there is in practice a diminution of this width, so that the elements in the join may be stated thus—

$$\frac{4W+2L}{L} - K = 4.6$$

$$\frac{4(.125)+2(.111)}{.111} = \frac{.5+.222}{.111} - K = 4.6$$

$$6.5 - 4.6 = 1.9 = K$$

With the needle thread, the take-up is augmented by extra intersections and by having to move over the covering thread which is usually a relatively thick count, and as shown in Fig. 12 this passes under each needle thread once in every stitch so that the ordinary measurement will be augmented by K representing those factors—

$$\frac{2T+L}{L} + K = 3.3$$

$$\frac{2(.056)+.111}{.111} + K = 3.3$$

$$3 + K = 3.3 \therefore K = .3$$

The analysis of the looper thread elements may be made by referring to Fig. 13 where the thread passes from side to side in each stitch as follows—two widths, plus seven stitch lengths, but in this case a deduction will require to be made owing to the manner in which the looper thread constricts the width of the stretch of the seam—

$$\frac{2W+7L}{L} - K = 8.2$$

$$\frac{2(.125)+7(.111)}{.111} - K = 8.2$$

$$\frac{1.027}{.111} = 9.25 - K = 8.2 \therefore K = 1.05$$

The comparative take-up figures for the remaining members of the double chainstitch group may now be recorded as ascertained in these tests with nine stitches per inch, using 3/60's cotton. The two-needle seam, which has three threads has take-up as follows—

1st needle	=	2.6	take-up
2nd needle	=	3.1	„
Looper	=	7.1	„
<hr/>			
Total	=	12.8	take-up.

The addition of a third needle, .125 inch from the second, gave the following details of take-up—

1st needle	=	3.3	take-up
2nd needle	=	3.0	"
3rd needle	=	2.6	"
Looper	=	8.5	"
<hr/>			
Total	=	17.4	take-up.

Finally the conversion of the seam into the five-thread variety by the addition of a covering thread gave the following particulars—

1st needle	=	4.28	take-up
2nd needle	=	4.28	"
3rd needle	=	3.33	"
Looper	=	7.00	"
Covering thread	=	4.61	"
<hr/>			
Total	=	23.5	take-up.

One series of each of those joins was tested in the usual way and the results are given in Fig. 14 where the breaking loads borne by each of the two, three, four, and five-thread joins are shown as a curve, whilst Fig. 15

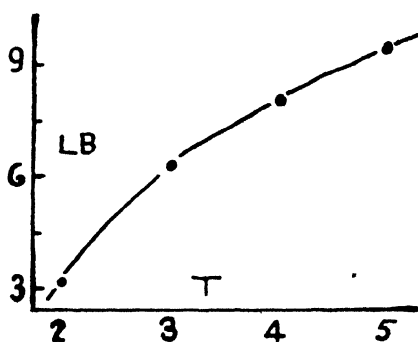


FIG. 14

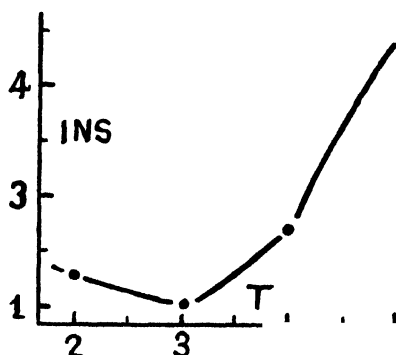


FIG. 15

gives the corresponding values for elongations. The great increase of take-up of thread which occurs between the four- and the five-thread join is very marked and is also noticeable in the curve for elongations which indicates a considerable increase with the addition of the final covering thread, and it is this yield of the seam which constitutes its most advantageous feature in joining fabrics. There is also a steady increase in strength of those seams as the number of stitches per inch are increased within moderate limits, beyond which the threads cut each other and produce a weak jointure. An increase of two stitches from eight to ten per inch almost doubles the strength of the three-thread double chainstitch join.

From the method of making those trials, it will be evident that the strength of the ground fabric should be taken into account in any numerical results, although in wear the strain has to be borne jointly by the threads used for stitching and the ground fabric. To ascertain this factor, it is suggested that the fabric should be tested by itself to find what strain is borne by it when the mean elongation of the seam test has been reached. To do this for any texture, it is most convenient to construct a stress-strain diagram by reading off values at short intervals during the test and showing the lb.

strain plotted against inches elongation. From this curve can then be read off conveniently the breaking load which corresponds to any degree of extension. To illustrate this a series of tests on the ground fabric were made for the chainstitch which showed a mean elongation of 3.4 inches. The ground fabric was cut into similar standard test lengths and the load was read off which the cloth took at this stage of elongation with the following details for ten trials—.9 lb., .8, .9, .9, .8, .9, .7, .9, .8, .8=.84 average. The mean breaking load of this series of tests showed 3.52 lb., so that this figure requires to be corrected by deduction—3.52 less .84=2.68 lb. as representing the net strength of the seam.

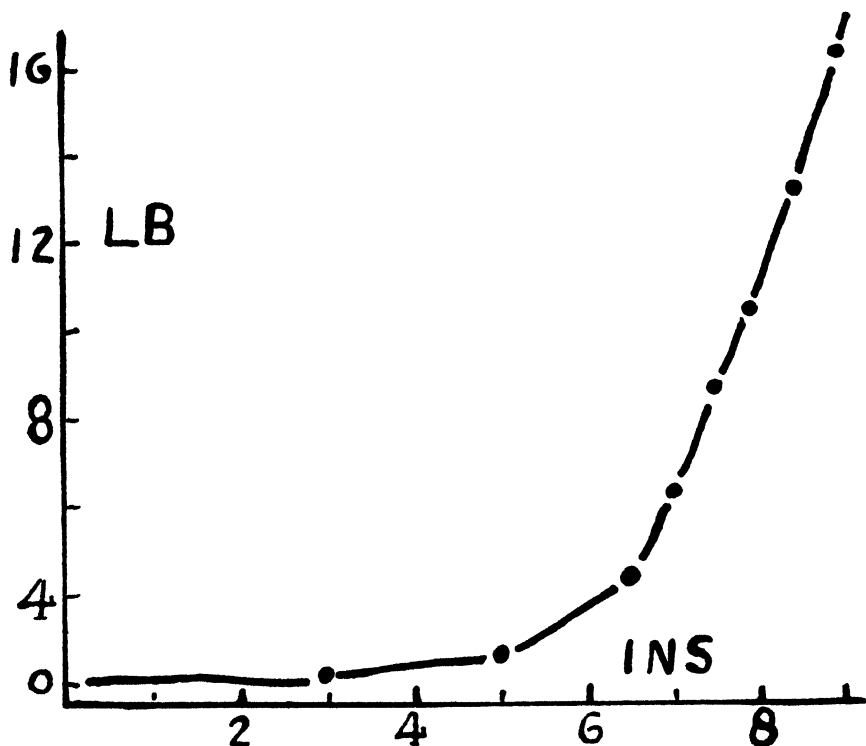


FIG. 17

A similar correction was made on the lockstitch series of tests which showed an average of 2.7 lb. breaking load and a mean elongation of 2.2 inches. The amount of pull registered by the ground fabric alone in ten trials is as follows—3 lb., .3, .4, .4, .3, .3, .2, .3, .3, .3=mean .31 lb. which, when deducted from 2.74=2.43 lb. as the net figure for the seam.

Overlock Seaming

This is one of the most important principles of joining knitted fabrics which are cut from material leaving a raw edge which may easily unrove and curl. The simplest form of overlock seam or overedge seam is the two-thread, of which one is supplied by a needle which pushes the thread through the fabric in the usual way, with a second thread introduced through a looper which is located under the fabric edge. Those two threads interlock with each other above and below the fabric edge alternately, and the looper thread is drawn round the edge to obscure any rawness of fabric. These may be

noticed in the diagram of this join given in Fig. 16 where the thread in black is that of the needle shown passing through the fabric in dotted lines, the looper thread appears in white intersecting with the needle thread. The main difference in this style of join as compared with the foregoing is that there is a bight a short distance from the edge and the two pieces are then drawn out straight, leaving the seam standing erect at right angles to the main body of fabric. This seam was made with 3/60's cotton in both looper and needle and the setting is 18 stitches per inch. The stress-strain diagram for a series of values of this test is given in Fig. 17, where the elongation in inches is given in the ordinates and the pounds breaking load on the abscissæ, and the final results show a breaking load of 16.2 lb. with an extension of 9 inches. A range of two-thread overlock seams was prepared with the given particulars of take-up and 14, 16, 18, and 20 stitches per inch.

A = 14 stitches per inch—Needle take-up	= 5.106
Looper take-up	= 5.102
Total	<u>= 10.208</u>

B = 16 stitches per inch—Needle take-up	= 6.48
Looper take-up	= 6.15
Total	<u>= 12.63</u>

C = 18 stitches per inch—Needle take-up	= 7.27
Looper take-up	= 6.98
Total	<u>= 14.25</u>

D = 22 stitches per inch—Needle take-up	= 8.27
Looper take-up	= 7.89
Total	<u>= 16.16</u>

The detailed readings of A and D are given herewith—

(A)	8 lb.	..	7.00 in.	(D)	17 lb	...	10.00 in
	7.4 "	...	7.50 "		16.8 "	...	10.50 "
	9.2 "	...	7.75 "		16.7 "	...	9.62 "
	7.2 "	...	6.25 "		15.3 "	...	10.25 "
	7.6 "	...	6.25 "		15.3 "	...	9.87 "
	9.2 "	...	6.87 "		16.4 "	...	10.25 "
	11.3 "	...	7.75 "		14.2 "	...	10.12 "
	10.8 "	...	7.12 "		18.0 "	...	10.50 "
	7.8 "	...	7.00 "		17.4 "	...	10.00 "
	8.8 "	...	6.37 "		16.0 "	...	10.62 "
	10.2 "	...	7.00 "		16.1 "	...	10.62 "
	11.0 "	...	6.25 "		17.4 "	...	10.87 "
	8.2 "	...	6.37 "		13.3 "	...	10.00 "
	10.1 "	...	6.00 "		18.0 "	...	10.50 "
	7.8 "	...	6.87 "		16.4 "	...	9.75 "
	8.6 "	...	6.37 "		18.4 "	...	10.25 "
	9.2 "	...	7.12 "		17.0 "	...	9.87 "
	9.6 "	...	7.00 "		15.9 "	...	9.37 "
	9.4 "	...	6.75 "		17.6 "	...	10.25 "
	9.0 "	...	7.12 "		17.5 "	...	10.00 "
Mean =	9 lb.	...	<u>6.8 in.</u>	Mean =	16.5 lb.	...	<u>10.16 in.</u>

In addition the results of the B series gave a mean breaking load of 14.16 lb. with 8.9 inches extension, whilst series C registered a breaking load of 17.6 lb. with 9.5 inches extension—

	Breaking Load	Extension
A—14 stitches per inch=	9 lb.	6.8 in.
B—16 " "	=14.16 "	8.9 "
C—18 " "	=17.60 "	9.5 "
D—20 " "	=16.50 "	10.16 "

An examination of the results for strength again indicates a gradual accretion until a certain limit of setting density is reached, after which denser stitching does not strengthen the seam but renders it less resistant to the strains of wear. In every set of conditions, therefore, it is of value to ascertain the optimum setting for the seam. Fig. 18 gives a graph where

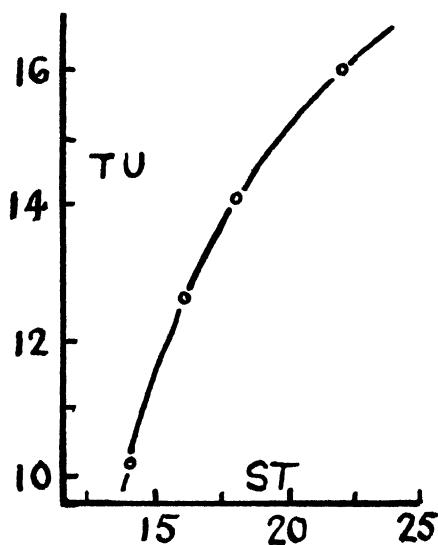


FIG 18

the total take-up of the yarn in the two-thread overlock seam is shown in relation to the stitches per inch, the take-up being represented by TU and the stitches per inch by ST. A comparison of the above results with those obtained for other seams or joins will show the superiority of the overlock type for most of the operations concerned with uniting cut knitted fabrics.

This style of seam can be further developed by the addition of a second looper which shares the intersection along the edge and gives a type of join which remains firm and closed under all strains which may be applied. A diagram of this type of seam is given in Fig. 19 where the needle thread, marked NT, is seen to be passing through the two plies of fabric and stretching underneath the distance of one stitch length. The first looper thread is marked LT1 and the other looper thread LT2. Thus the two cut edges are spanned by two threads, and all three intersect in loop form similar to what takes place in the knitted fabric itself. The following gives details of the take-up of each type of thread produced on this seam for three different numbers of stitches per inch.

A = 12 stitches per inch—needle thread	= 2.6 take-up
1st looper thread	= 6.0 "
2nd looper thread	= 4.0 "
Total	= 12.6 take-up.
<hr/>	
B = 14 stitches per inch—needle thread	= 3.43 take-up
1st looper thread	= 6.86 "
2nd looper thread	= 3.13 "
Total	= 13.42 take-up.
<hr/>	
C = 16 stitches per inch—needle thread	= 3.14 take-up
1st looper thread	= 8.00 "
2nd looper thread	= 3.69 "
Total	= 14.83 take-up.
<hr/>	

These seams when tested under the usual conditions showed the following results in mean breaking load and elongation—

A = 12 stitches per inch	= 6.9 lb.	5.5 in.
B = 14 " "	= 7.8 "	6.4 "
C = 16 " "	= 12.3 "	8.23 "

A correction for load taken by the ground fabric was made in the case of A with 12 stitches per inch where ten tests of strength at an elongation of 5.5 inches yielded the following figures—3 lb., .8, .3, .6, .6, .7, .6, .8, .3, .6 = .56 lb. average. This deduction = 6.9 less .56 = 6.34 lb. net breaking load.

In comparing the two-thread and the three-thread systems of joining fabrics, it will be noticed that the two-thread seam employs a much greater length of needle thread. In the two-thread seam, the length of needle thread is almost equal to that of the looper thread, in the three-thread join, however, there is a considerable reduction in the relative length of needle thread as compared with looper threads, and this is a point which influences cost as looper threads are generally lower in price than needle threads. In the three-thread, however, there is no additional strength from the addition of a thread, but positively the reverse, the strain appears to fall on the needle thread early in the tests and causes the seam to give way. The length of thread employed in the three-thread is increased not by 50% as one might assume but by a figure which is nearer 30 per cent. The relative strengths of these important joins is of such considerable practical importance that it is set out in graph form in Fig. 20 where the upper curve marked 2TO gives the results in pounds of 20 tests on the two-thread, whilst graph 3TO gives the corresponding results for the three-thread join.

Two outstanding factors which influence the considerable length of thread required to produce a unit length of overlock seam are—(A) The distance of the bight from the edge, as this fixes the distance which the looper threads have to extend round the border. The three elements concerned are from needle to edge, two fabric thicknesses and again a distance from edge to needle over the fabric. (B) Such joins are also made at a slacker tension than others owing to the elasticity which it is essential to produce in a seam required to yield almost the full stretch of the ground knitted material.

Taking the two-thread join as example and referring to Fig. 16, the factors in the take-up of the needle thread may be stated as follows, allowing for a bight of $\frac{1}{8}$ (.125) inch, with 16 stitches per inch, and a thickness of .026 inch.

Taking the needle thread, this will be composed of one stitch length, plus two thicknesses and twice the distance of the bight—

$$L = \frac{1}{16} \text{ inch} = .0625 \text{ inch}$$

$$\frac{L + 2T + 2B}{L} = \frac{.0625 + .056 + .25}{.0625} = \frac{.3685}{.0625} = 5.9 = U$$

For the looper thread, this may be regarded as having two fabric thicknesses and twice the bight thus—

$$\frac{2T + 2B}{L} = \frac{.052 + .25}{.0625} = 5 = U$$

In the case of the looper thread this amount in practice might be augmented by an allowance made for the slack tension at which this thread is worked to give the requisite elasticity.

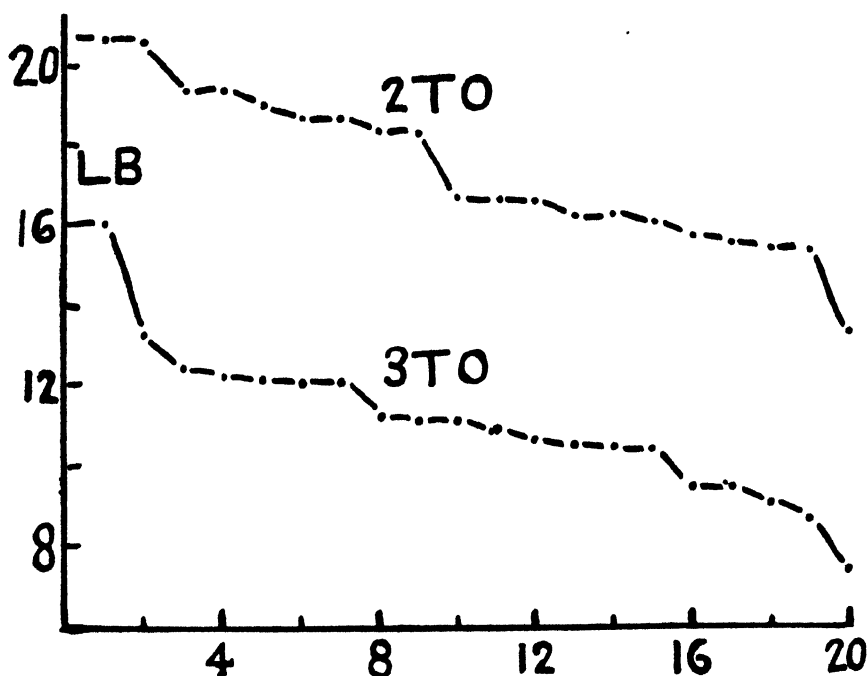


FIG. 20

Extending these examples to the three-thread join illustrated in Fig. 19 and with the same particulars of bight, thickness and stitches per inch, the take-up of the needle thread will be composed of two thicknesses plus one stitch length, along with an extra which may be taken as another stitch length shown by the oblique manner in which it occurs in the stitch—

$$\frac{2T + 2L}{L} = U$$

$$\frac{.052 + .125}{.0625} = 2.83 = \text{take-up.}$$

The first looper may be regarded as consisting of two bights plus a stitch length—

$$\frac{2B + L}{L} = \frac{.25 + .0625}{.0625} = 5 \text{ take-up.}$$

Taking the second looper, this comes half way round the edge equal to one thickness as the thread is double along with double bight=

$$\frac{2B+T}{L} = \frac{.25+.026}{.0625} = 4.4 \text{ take-up.}$$

In the case of the looper threads, these results would in practice be augmented by the slack tension at which they are worked, also there is often considerable difference between the relative lengths of one looper thread and another to give special effects in the join. The relation between the stitches per inch and the strength of the three-thread seam in pounds is given in Fig. 21 which shows a pronounced increase in breaking load as the stitches per inch are increased; beyond this point, however, it was found that increasing the number of stitches per inch had the effect of weakening the seam.

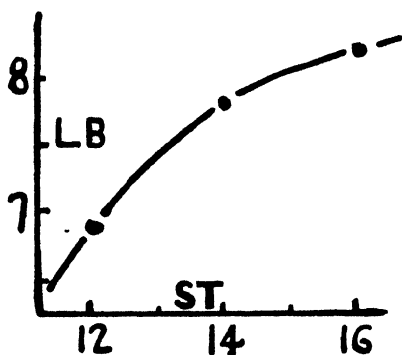


FIG. 21

One of the most important classes of seam used in the knitting section of the textile industry is known as the nine-thread seam, which stands in a class by itself as regards the method of production. The two cut fabrics which require to be joined are placed side by side and touch each other, the machine having a knife which trims the edges straight with each other before they pass into contact with needles and loopers. The nine threads are made up of four looper threads, four needle threads, and one covering thread which

moves backwards and forwards in snake-like fashion over the surface of the join. The treatment takes place over a single thickness of fabric, but the two edges are united by a system of intersection of needle and looper threads which virtually creates a new fabric over the area, the two pieces being joined together by the new fabric produced by the machine, so that the result is perfectly even and flat. The following give working details of the composition of this join, the threads employed in the needles being 3/60's cotton counts, the looper threads are of single cotton, 28's carded, whilst the covering thread is of 18's cotton or 300 deniers rayon yarn. If the material being joined is of wool, then the covering thread and the looper threads may be of wool, but the needle threads must be of cotton, as they have to pass so rapidly through the fabric, woollen threads in general being too fibrous and too stretchy for this purpose. An analysis of a join made from these yarns with 22 stitches per inch revealed the following figures for take-up of material—

Needle 1	= 2.18 take-up
Needle 2	= 2.79 "
Needle 3	= 2.58 "
Needle 4	= 2.09 "
Total	= 9.64 take-up for the needle threads.

Looper 1	= 5.21 take-up
Looper 2	= 5.21 "
Looper 3	= 4.90 "
Looper 4	= 5.85 "
Total	= 21.17 take-up for looper threads.

Covering thread = take-up of 8.
All these added give a total of 38.8 take-up.

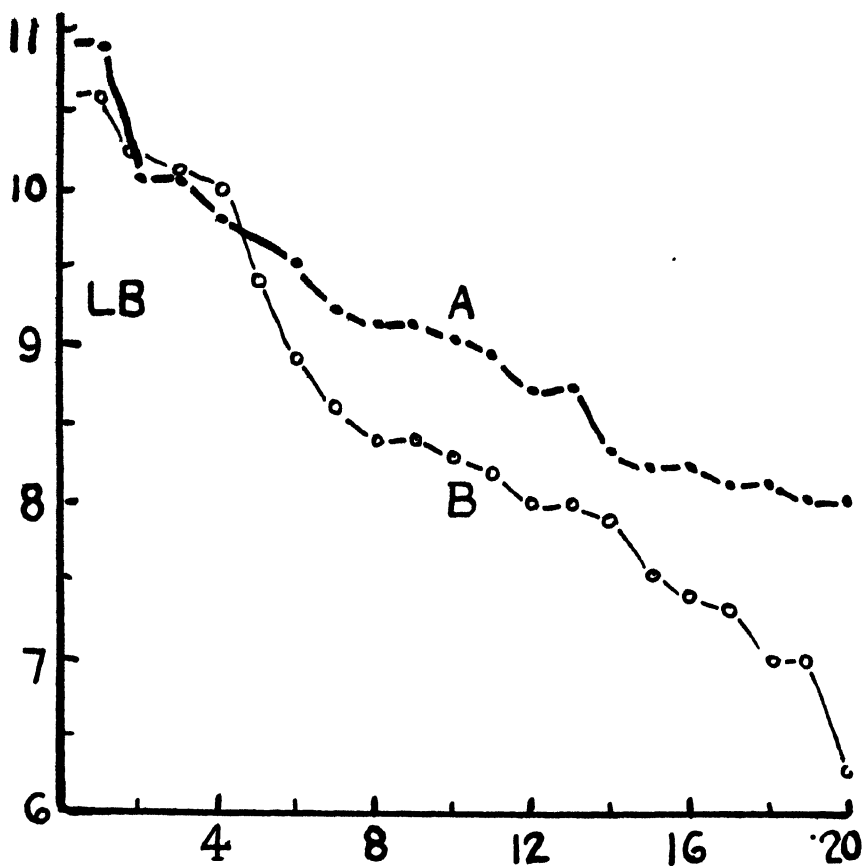


FIG. 22

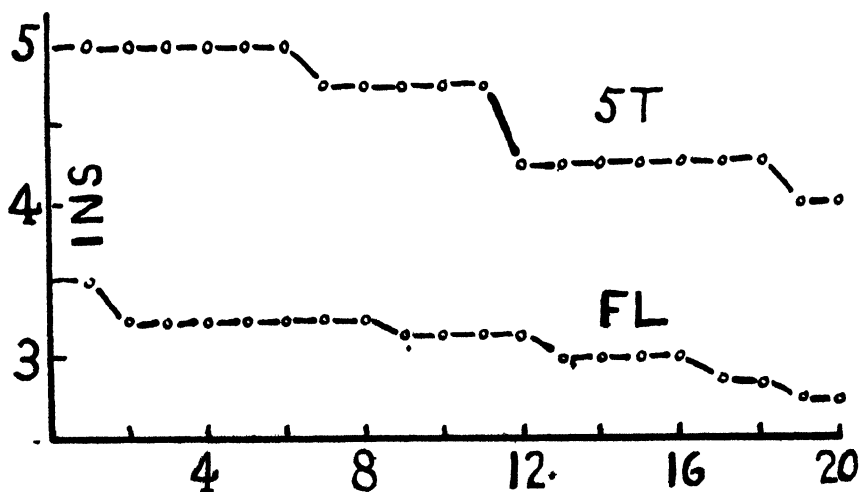


FIG. 23

The elements of this take-up may be stated for a width of seam $\frac{1}{4}$ inch, which gives $\frac{1}{2}$ inch as the distance between one needle and another. The looper thread traverses a triangular path in the seam, so that its intersection may be given as follows—two stitch lengths, one width to the next needle and on doubling back the thread forms the hypoteneuse of a triangle of which the base is the distance from one needle to the next and the second side a distance equal to a stitch length. The third side is obtained as follows, given that the length of stitch L is $\frac{1}{22}$ inch = .045 inch and the needle distance is $\frac{1}{12}$ inch = .083 inch.

The full expression of the take-up of a looper thread is as follows—

$$\frac{2L + W + \sqrt{L^2 + W^2}}{L} = U$$

$$\frac{.09 + .083 + .09}{.045} = \frac{.267}{.045} = 5.9 \text{ as take-up.}$$

The needle action is from one stitch to the next as L, then sufficient thread for the thickness, two-ply of thread.

$$\frac{L + 2T}{L} = U$$

$$\frac{.045 + .052}{.045} = \frac{.097}{.045} = 2.15 \text{ take-up.}$$

A series of tests made on this seam in the usual way gave the following particulars for 20 tests—

Breaking Load		Elongation
8.1 lb.	...	4 in.
8.0 "	...	3.87 "
9.0 "	...	4.0 "
9.8 "	...	3.5 "
8.0 "	...	3.75 "
8.7 "	...	3.75 "
8.7 "	...	3.62 "
9.5 "	...	4.37 "
8.9 "	...	3.75 "
10.9 "	...	4.00 "
9.2 "	...	4.12 "
9.1 "	...	3.87 "
9.5 "	...	3.87 "
8.3 "	...	3.50 "
8.2 "	...	3.75 "
8.2 "	...	3.75 "
9.1 "	...	3.62 "
8.1 "	...	3.62 "
10.1 "	...	3.87 "
10.1 "	...	3.5 "
Mean = 8.9 lb.	...	3.8 in.

It will be noticed that this system gives a small degree of elongation when compared with such types as the overlock, and the breaking load is also relatively less because the strain early in the test bears directly on the threads of the seam, and the strength of the fabric is a relatively small factor in the result. It is of practical value to employ this method in relation to different types of sewing and seaming materials to ascertain which combination of threads gives the most satisfactory results. Fig. 22 illustrates the results of two joins made with an alteration in the sewing cotton, the

counts being the same, and the two curves show a wide difference in performance. Graph A gives the results of the series just given side-by-side with a series marked B worked under identical conditions but in a different quality of material. In A there is a mean strength of 8.9 lb. with 3.8 inches extension as compared with a mean of 8.37 lb. and 3.1 inches extension for B. What is perhaps more important is that the combination A is more regular, having a deviation from the mean of 7% as compared with a deviation from the mean of 10.8% for example B.

Fig. 23 gives a graphical comparison of the five-thread seam and the nine-thread as regards elongation or extension. The upper curve shows the results of 20 tests on the five-thread and marked 5T, whilst the nine-thread seam is marked FL.

An example of costing the nine-thread join may be given for the following particulars and using the constants already provided—

Needle 1 of 3/60's cotton at 72d. per lb., take-up of	1.60
Needle 2 " " " " "	1.75
Needle 3 " " " " "	1.80
Needle 4 " " " " "	1.55
	<hr/> 6.7
Looper 1 of 24's worsted at 48d. per lb., take-up of	4.45
Looper 2 " " " " "	4.60
Looper 3 " " " " "	4.80
Looper 4 " " " " "	4.75
	<hr/> 18.6

Covering thread, 350 deniers rayon at 56d. per lb., take-up of 8.

Referring to the constants previously worked out the cost per 1,000 yards of seam is given as follows—

$$\text{Needle threads, } \frac{6.7 \times 30}{7} = 28.7\text{d.}$$

$$\text{Looper threads, } \frac{18.6 \times 25}{7} = 66.4\text{d.}$$

$$\text{Covering threads, } 8 \times 4.4 = 35.2\text{d.}$$

$$\text{Total} = \underline{\underline{130.3\text{d. per 1,000 yards}}}$$

SUMMARY

(1) Analyses of the chief types of sewing and seaming stitches are given and the principles of obtaining balance in those operations is indicated.

(2) A method is recommended for making comparisons between different types of joins as regards their fitness for any particular branch of the industry. The performance of different combinations of seaming materials can also be ascertained by the methods recommended.

(3) The principles underlying the take-up of seaming materials have been demonstrated along with the application of those methods to the practice of costing.

(4) An indication is given of the relation of strength of seam to the setting of stitches per inch and a method demonstrated of obtaining the optimum setting of seam for any given type of fabric.

Acknowledgment is made of the valuable assistance rendered in this investigation by Mr. W. E. Boswell, F.T.I., and Mr. G. H. Buckley, F.T.I., both of this department.

35—THE FLOW OF STARCH PASTES

(III) THE EFFECT OF SOAPS AND OTHER ELECTROLYTES ON THE APPARENT VISCOSITY OF HOT STARCH PASTES

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(British Cotton Industry Research Association)

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I—INTRODUCTION AND SUMMARY

The starch used as a sizing or finishing material in the textile industry is derived from a number of plant sources, and comes into the market through various channels. In the course of its manufacture it is treated with chemical reagents that may profoundly modify its character, and so determine its suitability for a particular purpose. It is therefore necessary to have means of measuring one or more of the properties that may serve to describe the character of a sample of starch, and the present paper gives an account of work done with this object. The property utilised so far is the apparent viscosity of a paste made from the material under investigation. The standard method described for preparing the paste and measuring its viscosity gives results which can be satisfactorily repeated. The work has necessarily involved an investigation of the effects of variations in the conditions of preparation of the pastes, and has been extended to include the effects of additions such as acids, alkalis, salts and soaps.

The viscosity of a normal liquid is most simply measured by determining the ratio of the time occupied in driving a known volume of liquid through a narrow tube to that required for the flow, under the same conditions, of an equal volume of a liquid of known viscosity, the viscosities of the two liquids being proportional to their times of flow provided that well-established corrections are applied. Previous work^{1,2} has shown that this simple treatment is inapplicable to starch pastes, and, strictly, no single figure can be assigned as the viscosity of such a paste. Given a standard driving force, or standard conditions of flow, it is possible to compare the time of flow of a starch paste

with the time of flow of a standard normal liquid, and to assign to the starch paste an apparent viscosity that describes its behaviour under the rigidly defined conditions of flow adopted for the measurement. In the present work the apparent viscosity has been measured by observation of the flow through a capillary tube under application of the pressure required to maintain a standard driving force for each unit of surface of the inner wall of the tube. The definition of these conditions is discussed in the experimental section of the paper. The apparent viscosity is then proportional to the time taken by the starch paste to flow under the specified conditions from a calibrated pipette. The viscosity of water at the temperature of the experiment is taken as unity, and the apparent relative viscosity of the starch paste is given as a multiple of this value. For simplicity this apparent relative viscosity is referred to throughout the paper as "viscosity." In the graphs it is convenient to plot viscosities on a logarithmic scale.

Preparation of the Pastes

In the preparation of the pastes the mixtures were never boiled, but were brought from cold to the temperature of the experiment by being stirred in a glass vessel supported in a water-bath maintained at 90° C.

It was soon found that the viscosity was highly dependent on the rate of stirring and on the age of the paste, and both duration and rate of stirring were kept under strict control. Stirring was interrupted at definite intervals to enable the viscosity to be measured. In general it was found that the viscosity fell as the age of the paste increased, but the time required for complete gelatinisation of the starch varied, and the highest viscosity was not always attained before measurements began.

Work has been done on a number of samples of starch, and the effect on the viscosity of adding to the pastes such reagents as acids, alkalis, salts and soaps has been observed. These substances were introduced after the starch had been fully gelatinised by heating and stirring with water for 30 minutes. The starches used were sago and farina (potato starch) which represent two rather extreme types of viscosity behaviour. A smaller number of experiments were made with maize starch.

The Rate of Fall of Viscosity

Farina pastes have a very high initial viscosity, which rapidly falls as stirring is continued. Sago pastes on the other hand have a comparatively low initial viscosity, and the subsequent rate of fall is less rapid than with farina. The initial viscosity of maize is intermediate between that of sago and farina, but its rate of fall is the least rapid of the starches examined. The rate of change of viscosity on storage is found to depend on the condition of acidity or alkalinity of the pastes. For sago the change is least rapid when the paste is neutral or faintly alkaline (pH 7–8). Farina pastes are most stable when slightly acid (pH 5), whilst maize is subject to little change in the slightly acid region between pH 4.5 and 6.5. Pastes of higher acidity than those quoted for the respective starches are subject to a rapid fall of viscosity which is accelerated the more acid the paste is made. In more alkaline pastes, except in those to which soap is added, the viscosity also falls at an increasing rate with increasing alkalinity.

Effect of Copper and Copper Salts

Two sets of stirrers have been used, constructed respectively of copper and of stainless steel, and the viscosity has been found to depend on which of these

was in use. With stainless steel stirrers pastes are obtained with higher viscosity and lower rate of change with time than when the stirrers are of copper. It has been found that a paste can dissolve an appreciable amount of copper from a copper vessel in which it is prepared, and also that copper sulphate is extremely effective in promoting the fall of viscosity of a sago paste on storage.

Effect of Acidity and Alkalinity

In order to compare pastes made up in different ways or with different ingredients it has been usual to measure the viscosity at standard times after the heating begins. Compared in this way, 60 minutes after the start of an experiment, pastes in which the acidity is controlled by the addition of buffer salts, acids or alkalis, have their highest viscosity in the slightly acid region of pH 4–5. At higher acidities than this the viscosity is progressively less as the acidity increases. Between pH 4–5 and neutrality, there is also a progressive fall of viscosity with decreasing acidity. Maize and farina pastes continue to exhibit a lower viscosity as the alkalinity increases, but alkaline sago pastes are not less viscous and in certain circumstances may be more viscous than the neutral pastes.

A summarising table (Table I) is given to illustrate the magnitudes of the changes involved when sago, farina, and maize pastes are made acid, neutral or alkaline with buffer salts.

Table I

Apparent Relative Viscosities of Starch Pastes in the Acid, Neutral, and Alkaline State. The Pastes were heated for 90 minutes at 90° C. The Viscosity of Water at 90° C. is taken as 1.

				5% Sago	3% Farina	4% Maize
No addition ...	...	...	...	35	347	209
Slightly acid	(buffered at pH 4·5)	...	...	37	64	186
Neutral	(pH 7·0)	...	...	19	43	141
Slightly alkaline	(pH 10·0)	...	...	19	34	39

Effect of Salts on Viscosity

Neutral salts lower the viscosity of sago slightly, but farina pastes are much more sensitive to the presence of salts. Table II shows the viscosities at 90 minutes of sago and farina pastes with the addition of 0·05% of sodium chloride on the paste, and in addition the viscosities of 5% sago pastes with equivalent amounts of sodium sulphate and calcium, zinc and magnesium chlorides.

Table II

Apparent Relative Viscosity of Starch Pastes at 90° C., after 90 minutes heating. (Water = 1)

Addition	5% Sago	4% Farina	Addition	5% Sago
None ...	35	501	Calcium chloride ...	28
Sodium chloride ...	32	188	Zinc chloride ...	21
Sodium sulphate ...	33	—	Magnesium chloride	28

Practically the full change of viscosity is brought about by a quantity of salt as small as 0·006% of sodium chloride on the weight of the paste. Additions greater than this produce only a slight further fall, and in sufficiently high concentration may even cause an increase. Farina is sensitive not only to neutral salts but also to the salts used in buffer mixtures, and on this account farina pastes, the acidity of which has been controlled by buffers, have a much lower level of viscosity than those prepared from farina and water alone.

Soaps

In low concentration soaps behave towards sago pastes like mild alkalis, and lower the viscosity, but as the soap concentration is increased the viscosity reaches a minimum, and then rises rapidly. In a 5% paste the minimum occurs at a soap concentration of approximately 0.15% of the paste (0.005*N*), but the rapidity of the initial fall and subsequent rise depends on the kind of soap. With stearates, the initial fall in viscosity is less and the subsequent rise more rapid than with oleates. The effect is not due to the increasing alkalinity alone, for the pastes even with the most concentrated soap solution are not more alkaline than *pH* 9.0, and the effect must be ascribed to a specific action between the soap and the starch. Four per cent. farina pastes give similar results to 5% sago pastes, but with 2% farina pastes the viscosity continues to fall with increasing soap concentration up to the limit of concentration employed in the experiments.

Castor oil soap (soluble oil, sodium ricinoleate) lowers the viscosity of sago pastes at all concentrations up to 0.6% of the paste (0.020 *N*).

In addition soaps have a considerable stabilising effect on starch pastes, and at about the concentration of soap that gives the lowest viscosity the change of viscosity with time is least rapid.

Tallow

Tallow by itself is without influence on the viscosity of a sago paste in which it is incorporated. If soap is present, however, the effect of the tallow is to counteract that of the soap, and the paste behaves as if it contained a lower soap concentration than it actually does. Tallow may therefore raise or lower the viscosity of a paste containing soap, according to the concentration of the soap.

Mixtures of Starches

In mixtures of sago and farina of the same total starch content, both unbuffered and buffered at *pH* 5, the viscosity increases with increasing farina content. The stability of these mixtures varies with their composition, and a mixture containing three parts of sago to one of farina is more stable than either of the single starches or a mixture of any other composition.

II—PREPARATION OF THE PASTES AND MEASUREMENT OF THE APPARENT VISCOSITY

(a) Description of Apparatus

The pastes are prepared in the apparatus shown in Fig. 1. A is a vessel of resistance glass 9 inches deep and 2½ inches in internal diameter. It is fitted with a rubber stopper, which carries the viscometer V, an inlet funnel F, and a guide G for the stirrer S. There is also an outlet hole O, down which a rubber tube can be inserted. The vessel A is clamped in position in a glass-walled thermostat,* with its upper end just above the water level. A stirring shaft is mounted above the thermostat, driven by direct coupling to a D.C. motor with variable speed control. The shaft carries a revolution counter, and through a bevel gear drives a vertical spindle to which the upper end of the stirrer is attached.

*A pyrex tank 18 in. × 12 in. × 12 in. deep has been used as a thermostat, and is very much superior to the usual metal vessel with windows. The pyrex glass appears to be quite immune to the erosion and cracking that occur with soft glass windows immersed in water at a high temperature.

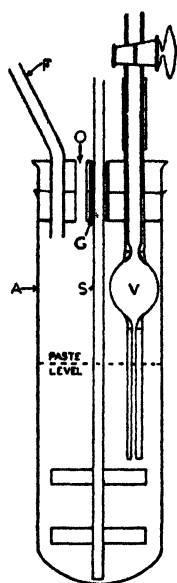


FIG. I

The viscometer bulb is connected through a glass tap to the exhaust and pressure line, and may be alternately filled and discharged through the capillary by the application of suction or air pressure through suitable connections (not shown in the diagram). Three vessels are mounted side by side in the thermostat, the stirrers being driven from the same shaft.

(b) Viscometer Constants

It has been shown in previous work^{8,9} that it is impossible to specify the viscosity of a starch paste by a single figure since the apparent viscosity decreases as the rate of flow in a given channel increases. If, however, the conditions of flow are standardised by specifying either the shearing stress or the rate of shear at which a measurement is made, the same value of the apparent viscosity of a paste is obtained from measurements made in different viscometers. It is experimentally easy when capillary viscometers are used to prescribe that measurements shall always be made at a standard shearing stress, and this has been done in the present work.

In a capillary viscometer the shearing stress at the capillary wall is given by the expression $Pr/2l$, where r is the radius and l the length of the capillary tube, and P is the hydrostatic pressure employed to force the liquid through the tube. The requisite value of P is ascertained by dividing the chosen value of the shearing stress by $r/2l$ which is determined as shown below. In the present work the value of $Pr/2l$ was arbitrarily selected as 100 dynes per sq. cm., i.e. $\log Pr/2l = 2$.

The volume V of the bulb and the radius of the capillary were determined by the mercury method, and the length of the capillary by direct measurement with a travelling microscope. A method of checking the dimensions is to determine the rate of flow in the instrument of a liquid of known viscosity, and to use the equation

$$\eta = \frac{P\pi r^4 t}{8lV}$$

to determine r , l and V being known.

Table III
Viscometer Constants

By Direct Measurement							By Cane Sugar Calibration		
(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)
Visco- meter	Radius of Capillary r cm.	Length of Capillary l cm.	Volume of Bulb V c.c.	$r/2l$ $\times 10^3$	r^3/V $\times 10^4$	$h = P/gd$ $= 100/(rgd/2l)$ cm. of water	Radius of Capillary r cm.	$r/2l$ $\times 10^3$	r^3/V $\times 10^4$
A	0.0658	9.12	5.26	3.69	0.542	28.25	0.0658	3.69	0.542
B	0.0641	8.81	5.31	3.64	0.497	28.0	0.0634	3.60	0.493
C	0.0652	8.93	5.40	3.65	0.512	27.9	0.0646	3.61	0.509
H	0.0885	8.63	5.20	5.13	1.334	19.9	0.0859	4.98	1.310

Both procedures have been followed. Cane sugar solution was chosen as the calibrating liquid, the viscosity data of Bingham and Jackson² being used. The measurements obtained by both methods are given in Table III, and the values of $r/2l$ and r^2/V , which determine respectively the shearing stress and the rate of shear, are shown. As a method of weighting the individual measurements of r , the value of $r/2l$ has been taken from col. (v) and the value of r^2/V from col. (x).

The value of the height h given in col. (vii) is the hydrostatic head required in order to produce at the capillary wall the arbitrarily chosen shearing stress. It is made up of two portions, the head indicated on the manometer of the air reservoir, and the mean hydrostatic head in the viscometer during an experiment. The latter is taken as h_0 , the arithmetic mean in centimetres of the heights of the top and bottom marks on the bulb above the level of liquid in the vessel, the density of a 5% starch paste at 90° being taken as unity, a value sufficiently accurate for this purpose. In order therefore to maintain a shearing stress of $Pr/2l=100$ the reservoir pressure must be $h = h_0$.

When the time of flow is rapid a correction for the kinetic energy of the fluid must be applied. Following Bingham,¹ a pressure p_k is subtracted from p , and the actual value of $Pr/2l$ is therefore less than 100 in these circumstances. It so happens, however, that starch pastes that have a low viscosity, and therefore a rapid time of flow with a considerable kinetic energy correction, behave almost like normal liquids, and no serious error is introduced by the departure of $Pr/2l$ from the standard value.

For calculating the results, curves are plotted for each viscometer relating the time of flow to the logarithm of the apparent viscosity. The value of $\log \eta$ for water is taken as 3.500 at 90° C., and this is subtracted from the log apparent viscosity to give log apparent relative viscosity ("log viscosity") $\log \eta_r$.

(c) Preparation of the Pastes

Preliminary experiments indicated that in order to obtain reproducible results the conditions of preparation of the pastes must be strictly controlled. During the course of the work a number of variables have been investigated in some detail, but others have been controlled at a standard value throughout, and it is convenient at this point to summarise the information gained in the preliminary work, before describing the standard procedure finally adopted.

(i) *Concentration*—The higher the concentration the higher is the viscosity of the paste. For pastes prepared in an identical way, a linear relationship has been found between the concentration and the logarithm of the apparent viscosity, in agreement with experience in earlier work.⁸ This relationship holds over a considerable range, but not in general down to zero concentration.

(ii) *Rate of stirring of the paste*—The effect of stirring rate on the viscosity of a 5% sago paste is illustrated in Fig. 2. In these experiments the starch-water mixture was poured into the tube with the stirrer running, and the stirring continued for ten minutes. The paste was then allowed to stand for five minutes, stirred for ten minutes, again allowed to stand for five minutes, and so on, the stirring rate throughout each experiment being the same, but varying from experiment to experiment. During the five-minute resting periods a portion of the paste was sucked up into the viscometer and a measurement made. It will be seen from Fig. 2 that a high rate of stirring gives a more rapid fall of viscosity than a low rate of stirring. The dotted

curve in Fig. 2 refers to an unstirred paste, which after 90 minutes' storage was stirred at 500 r.p.m. for ten minutes, and its viscosity again measured; the viscosity fell to a value close to that of a paste that had been stirred at this rate throughout.

The standard stirring rate of 500 r.p.m. was chosen for all subsequent experiments.

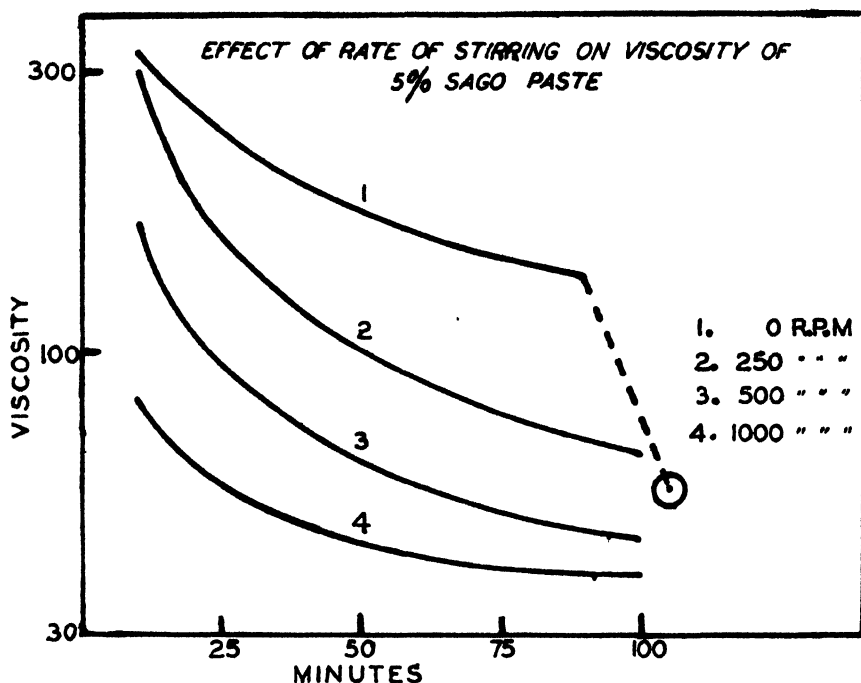


FIG. 2

(iii) *Age of the pastes*—It is well known that the viscosity of a starch paste changes with time. The change is almost invariably a fall of viscosity, but the rapidity of the change depends on various factors, and particularly on additions of salts, soaps, acids, etc., to the pastes. Sometimes, particularly with plain maize pastes and at low stirring rates, there is an initial rise of viscosity to a maximum, followed by the usual fall. It is of course obvious that in all pastes this initial rise to a maximum must take place, but usually the highest viscosity has been passed before any measurements are made.

(iv) *Temperature*—A few measurements showed that the effect of variation of the temperature of preparation was considerable, and all observations recorded in this paper were made at 90° C.

(d) Standard Procedure for Preparation and Measurement of the Pastes

Sufficient starch of known moisture content is weighed out to make a paste of the required concentration when added to 250 gms. of water. It is suspended in 200 c.c. cold water in a beaker, the stirrer is set in motion at 500 r.p.m., and the suspension poured in through the funnel. The time is noted, and the beaker is quickly rinsed out with the remaining 50 c.c. water. The starch quickly gelatinises, and reaches temperature equilibrium in seven to eight minutes. The stirring is continued at the standard rate for ten minutes. The motor is then stopped for five minutes, run for ten minutes,

stopped for five minutes, and so on. The measurements are made during the resting periods. A portion of the paste is sucked up into the viscometer bulb, above the level of the upper mark. The pressure of the reservoir is adjusted to the correct value, and the time of outflow of the paste under this pressure is measured with a stop-watch. Usually two experiments are run side by side, the second being started 15 minutes after the first.

When the effects of added substances are investigated a plain paste is first made by heating the starch with 170–200 c.c. water in the manner described for 30 minutes. The salt or other material, dissolved in 50–80 c.c. water, is then introduced at the commencement of the third stirring period, and measurements are begun in the next period of rest, 40 minutes from the start, and continued at 15-minute intervals.

The observations are plotted as $\log \eta_*$ against the time from the commencement of the experiment.

At the conclusion of an experiment the paste is transferred by suction into a flask. Measurements of the pH of the cold paste by the quinhydrone electrode and of concentration by drying at 110° C. are made on this sample. The vessel is cleaned out by successive washes with dilute alkali, dilute acid, and hot water.

(e) Expression of Results

(i) *Apparent relative viscosity*—It has been found convenient to express the results as apparent viscosities relative to that of water at the same temperature at a series of arbitrary times, 30, 60, and 90 minutes from the start of the experiment. These values are distinguished as η_{30} , η_{60} , etc. In order to avoid an unduly extended scale the logarithms of these quantities are plotted in the graphs.

(ii) *Stability of the pastes*—The coefficient of stability of a paste during any period may be defined as the ratio of the viscosity at the end to that at the beginning of the period. For example, the coefficient of stability of a paste between 60 and 90 minutes ($S_{90/60}$) from the start of the experiment is η_{90}/η_{60} . If no change in viscosity has taken place during the interval the paste is perfectly stable and the value of the ratio is unity. The more rapid the fall of viscosity during the period the lower is the stability and the lower the value of the ratio. A value of the ratio greater than unity indicates that there has been an increase in viscosity during the interval in question.

(f) The Viscosity-Time Curve for Plain Pastes

Typical curves for sago, farina and maize pastes are shown in Fig. 3. In the maize pastes the viscosity rises to a maximum and then slowly falls, but this maximum is not shown in the curves for the other starches, which show a continuous fall from the first observation. In the early stages the farina pastes have very high viscosities, and it is not possible to obtain a measurement in the viscometers employed even with a 3% farina paste until it has been heated for 70 minutes. Sago pastes have the lowest viscosities, a 5% sago being much less viscous than a 4% maize. Different samples of the same variety of starch may, however, differ considerably, but experiments on a number of starches of each variety (Table IV) have shown that the samples used in these experiments, marked with an asterisk in the table, are fairly typical of their respective classes.

Comparison of different pastes has been made only after the maximum in the time curve has been passed. At this stage the rate of change of viscosity

during the period of the experiment is least for maize and greatest for farina, sago lying between the two. Although the rate of change becomes less rapid with increasing age (Fig. 19), the pastes do not reach a steady final viscosity.

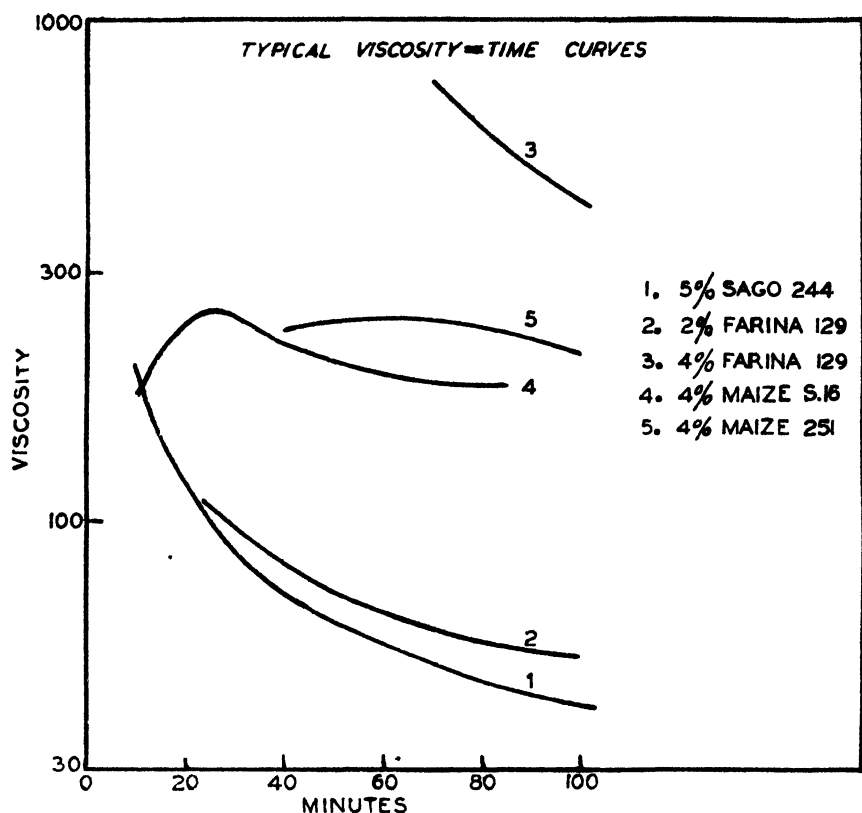


FIG. 3

Table IV

Viscosity and Stability of Sago, Farina, and Maize Pastes under Standard Conditions at 90° C.

Sample No.	η_{60}	$S_{60/30}$	$S_{90/60}$	Sample No.	η_{60}	$S_{60/30}$	$S_{90/60}$
5% Sago pastes—				4% Farina pastes—			
S35	63.1	.69	.79	S18	935	—	.63
S28	67.9	.75	.81	S13	933	—	.54
316	53.3	.60	.74	*129	501 (90 mins.)	—	—
*244	59.2	.67	.82				
S39	52.2	.68	.80	4% Maize pastes—			
317	50.0	.68	.71	324A	288	.86	.80
S17	45.7	.72	.84	S16	203	.81	.90
314	43.2	.75	.87	*251	248	.99	.94
313	42.7	.74	.87				
309B	34.3	.64	.86				
S14	44.5	.88	.96				
309A	31.6	.73	.83				

*These starches were used in the other work described in the paper.

(g) Control and Measurement of Hydrogen Ion Concentration

The pH of the pastes was controlled by additions of weak organic acids, caustic soda, and buffer salts to the gelatinised starch, 30 minutes after the

commencement of heating. The buffers employed⁴ were the phosphate, borate-potassium chloride, and phthalate mixtures of Clark and Lubs, the citrate-hydrochloric acid mixture of Sørensen, and the acetate mixture of Walpole, the final concentrations of anion in the pastes being acetate, 0.16 *M*; phosphate, 0.04 *M*; phthalate, 0.04 *M*; borate-KCl, 0.04 *M* in borate and 0.04 *M* in Cl'; citrate-HCl, 0.02 *M* in citrate+Cl'. Lactic and tartaric acids were employed in concentrations up to 0.02 *N*, and sodium hydroxide up to 0.075 *N*.

When the viscosity measurements were completed the paste was transferred to a stoppered flask and allowed to cool for about an hour. Ten to 20 c.c. of the paste were then placed in an electrode vessel fitted with a platinum or gold electrode and thoroughly mixed with about 0.1 gm. of quinhydrone, previously ground to pass a 30's mesh sieve. The vessel was immersed in a thermostat at 25° C. About half an hour was allowed for the attainment of temperature equilibrium, and the E.M.F. was measured against a saturated potassium chloride-calomel half cell, saturated potassium chloride being used as the junction liquid, and the *pH* calculated from the formula—

$$pH = \frac{.453 - E}{.0591}$$

where *E* is the measured E.M.F. of the chain. No difficulty was experienced in measurements on pastes buffered at a lower *pH* than 9, but in more alkaline pastes a steady E.M.F. was not attained. Pastes containing small amounts of soap gave results of satisfactory reproducibility, but with higher soap concentrations, and particularly with the 4% farina and 7% sago pastes, although as a rule steady E.M.F.'s were obtained in any one measurement, agreement between duplicates was not good, even when the E.M.F. indicated a *pH* less than 9. These pastes were extremely viscous, and uniform distribution of the quinhydrone throughout the paste was very difficult; it is probable that the variations were caused by failure of the quinhydrone to saturate the paste in the vicinity of the electrode.

The *pH* of an unbuffered starch paste is not easy to measure on account of the low conductivity of the material. Pastes containing neutral salts have a higher conductivity, with consequent higher sensitivity in the electrical measurement, but in the absence of adequate buffering the observed *pH* values can hardly be relied upon, owing to the effect that small quantities of impurity may exert on the hydrogen ion concentration. A few results for unbuffered pastes are, however, quoted.

No other method of measuring *pH* was available during the greater part of the work, but in the later stages some measurements made with the glass electrode gave results for neutral and acid pastes within 0.1 *pH* unit of the value obtained with the quinhydrone electrode.

The concentration of the buffer mixture in all the pastes except those buffered with the citrate-HCl mixture was four-fifths of that given in the tables quoted by Clark; dilution to this extent does not appreciably alter the *pH* of a buffer solution. The measured *pH* of the paste was usually within 0.1 *pH* unit of the nominal *pH* of the starch-free buffer, the greatest discrepancies being among the alkaline pastes.

No attempt has been made to measure *pH* values at 90° C., the temperature of the viscosity measurements. It has been shown by Walbum¹⁸ and by Kolthoff and Tekelenburg¹² that there is very little change in the *pH* of most buffer mixtures between 10° and 60° C. With the exception of the borate

mixtures none of the buffers used in these experiments has an important temperature coefficient between these limits, and it appears unlikely that the pH values at 90° will differ considerably from those at 25° , except in the alkaline borate pastes, which in any case are not susceptible of accurate measurement by the quinhydrone electrode.

In the tables the measured pH is quoted for pastes less alkaline than pH 9. At higher pH values than this the nominal pH of the buffer is given in brackets.

III—EXPERIMENTAL RESULTS

(a) Effect of Varying Acidity

(i) On the magnitude of the viscosity.

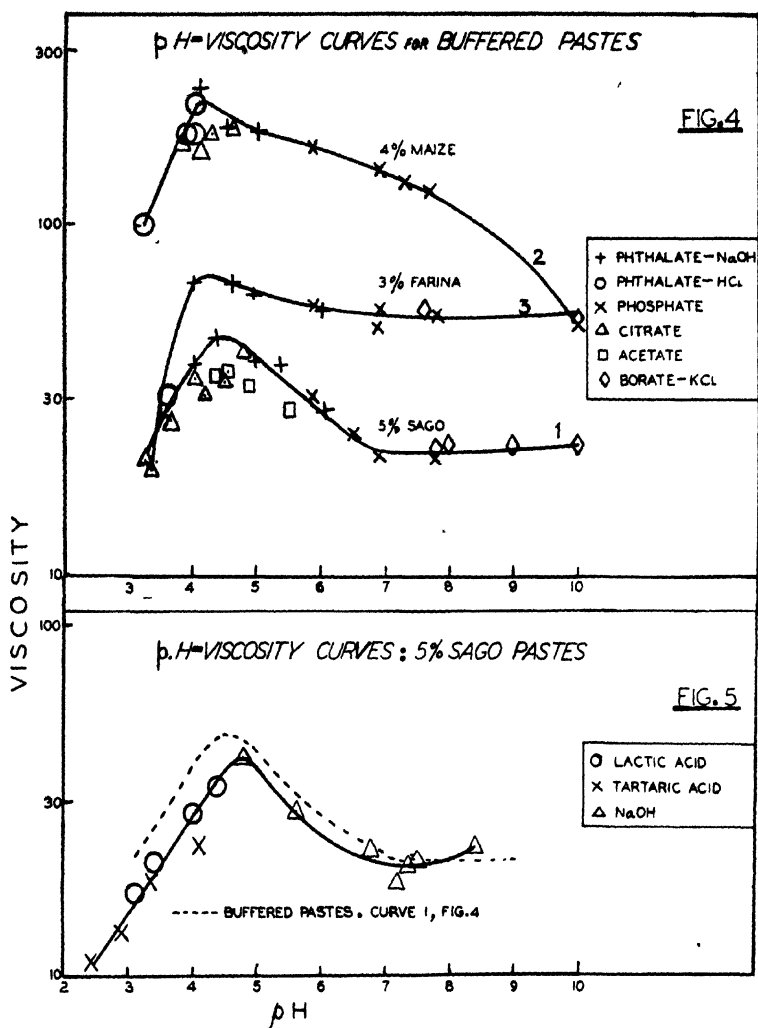
The viscosity data for 5% sago, 4% maize and 3% farina pastes of controlled hydrogen ion concentrations are given in Tables V–IX, and the values of η_{80} are plotted against pH in Figs. 4–7. For 5% sago pastes the curve (1 of Fig. 4) shows a maximum at about pH 4.5, and falls fairly steeply on both sides of this. On the acid side of the maximum the fall is probably continuous, but on the alkaline side it is checked at about pH 7, and the viscosity remains fairly constant up to pH 10, which was regarded as the useful limit of these experiments. Fig. 5 gives a similar curve for pastes with additions of tartaric and lactic acids and caustic soda, and the curve for the buffered pastes is repeated in this diagram.

Table V
Viscosity of Buffered 5% Sago Pastes at 90° C. (Copper Stirrers)

<i>Citrate—HCl Buffer—</i>							
pH	...	...	3.26	3.66	4.17	4.50	4.86
η_{80}	...	...	21.4	27.5	32.4	35.5	43.7
$S_{90/80}$	...	...	.70	.74	.81	.85	.83
<i>Phthalate Buffer—</i>							
pH	...	...	4.03	4.40	4.80	4.99	5.38
η_{80}	...	...	39.8	47.9	44.7	40.7	39.8
$S_{90/80}$	...	...	.79	.79	.82	.87	.79
<i>Acetate Buffer—</i>							
pH	...	...	3.60	4.35	4.55	4.90	5.52
η_{80}	...	...	29.5	37.2	38.9	34.7	29.5
$S_{90/80}$	...	...	.70	.70	.71	.72	.76
<i>Phosphate Buffer—</i>							
pH	...	...	5.90	6.48	6.92	7.80	
η_{80}	...	...	32.4	25.1	21.9	21.7	
$S_{90/80}$	...	...	.72	.79	.87	.87	
<i>Borate—KCl Buffer—</i>							
pH	...	...	7.71	7.88	(9.0)	(10.0)	
η_{80}	...	...	23.2	24.0	24.0	24.0	
$S_{90/80}$	...	...	.86	.85	.83	.81	

Table VI
Effect of Lactic and Tartaric Acids on the Viscosity of 5% Sago Pastes at 90° C. (Copper Stirrers)

Acid concentration in paste, equivalents per litre				Acid concentration in paste, equivalents per litre			
	pH of paste	η_{80}	$S_{90/80}$		pH of paste	η_{80}	$S_{90/80}$
Lactic, .001	4.4	35.1	.83	Tartaric, .001	4.1	24.0	.72
" .003	4.0	29.2	.71	" .003	3.4	18.8	.74
" .010	3.4	21.1	.70	" .010	2.9	13.2	.73
" .020	3.1	17.3	.69	" .020	2.5	11.0	.76



FIGS. 4-5

Table VII
Effect of Sodium Hydroxide on the Viscosity of 5% Sago Pastes at 90° C.
(Copper Stirrers)

Concentration of NaOH in paste, equivalents per litre	pH of paste	Log η_{60}	$S_{90/60}$	Concentration of NaOH in paste, equivalents per litre	pH of paste	Log η_{60}	$S_{90/60}$
0	4.8	42.2	.81	0.0040	7.4	20.7	.86
0.0002	—	39.4	.84	0.0060	7.5	21.2	.86
0.0004	5.6	30.1	.87	0.0075	—	25.4	.87
0.0010	6.8	23.4	.91	0.0100	8.4	23.7	.78
0.0020	7.2	18.6	.89	0.0750	—	30.2	.73

Table VIII

Viscosity of Buffered 3% Farina Pastes at 90° C. (Copper Stirrers)

pH	η_{90}	$S_{90/60}$	Buffer	pH	η_{90}	$S_{90/60}$	Buffer
5.6	Very high	—	No addition	5.90	58.9	.85	Phosphate
3.36	20.0	.62	Citrate-HCl	6.88	51.2	.83	"
3.64	32.4	.61	Phthalate	6.94	57.9	.76	"
4.01	68.9	.78	"	7.81	55.6	.72	"
4.62	68.6	.92	"	7.60	58.6	.84	Borate-KCl
4.98	63.1	.93	"	(10.0)	54.3	.62	"
6.02	57.5	.87	"				

Table IX

Viscosity of Buffered 4% Maize Pastes at 90° C. (Copper Stirrers)

pH	η_{90}	$S_{90/60}$	Buffer	pH	η_{90}	$S_{90/60}$	Buffer
6.3	240	.96	No addition	4.11	243	.83	Phthalate
3.83	174	.79	Citrate-HCl	4.53	191	.98	"
4.12	162	.89	"	5.02	186	1.05	"
4.30	182	.89	"	5.90	167	.98	Phosphate
4.59	189	.91	"	6.90	145	.98	"
3.25	100	.25	Phthalate	7.68	125	.55	"
3.92	183	.73	"	7.28	132	.90	Borate-KCl
4.04	182	.81	"	(10.0)	52	.87	"
4.05	224	.79	"				

The hydrogen ion concentration is the major factor governing the viscosity of these pastes, but there is also a definite though small specific influence of the anion. At the same pH tartaric acid produces a lower viscosity than lactic acid. Where the phthalate and phosphate curves (Fig. 4) cover the same pH range they are coincident, but a borate-KCl paste appears to have a rather higher viscosity than a phosphate paste of the same acidity. The acetate curve lies consistently lower than the phthalate curve in the same pH region. These differences between the anions do not, however, affect the main features of the curve, but merely change its general level. The viscosity maximum occurs at practically the same pH whatever the other ions present.

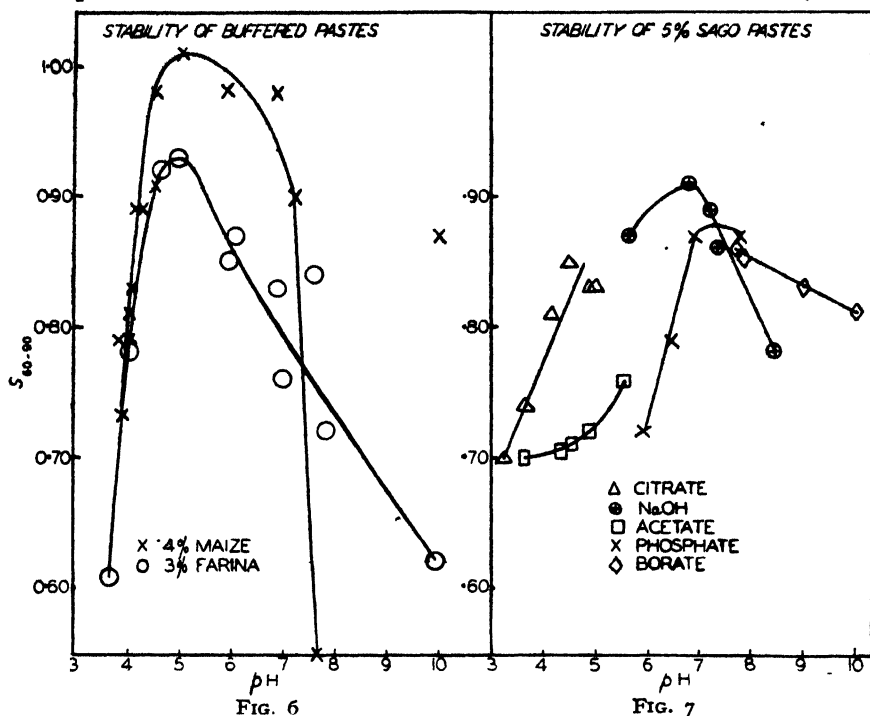
Similar curves have been obtained with buffered 4% maize and 3% farina pastes (Fig. 4, curves 2 and 3). In both these the maximum viscosity occurs at pH 4.0-4.5, values nearly identical with that defining the sago maximum. The curves show the same rapid fall on the acid side of this maximum, and a slower fall as the pastes are made more alkaline. With maize the fall of viscosity is not checked at pH 7, but continues as far as pH 10.

The viscosity of a sago paste without addition of any kind is close to that of a buffered paste of the same pH, and is near the viscosity maximum. An unbuffered maize paste on the other hand has a pH of about 6.3, and has a considerably higher viscosity than a paste buffered at this value. With farina the difference between the plain paste (pH 5.6) and the buffered pastes is still greater; after 60 minutes' heating a 3% unbuffered farina paste was still too viscous to be measured in the viscometers available, and was probably seven or eight times as viscous as any buffered paste.

(ii) pH and stability of buffered pastes.

The rate of change of viscosity differs at different pH values. This variation is illustrated by the figures for the stability of the pastes, $S_{90/60}$, defined as the ratio of the viscosity at 90 minutes to that at 60 minutes, η_{90}/η_{60} , which is plotted against pH for these starches in Figs. 6 and 7. The curve shows that for each starch there is a maximum stability over some pH region. This is most definite for maize, for which the limits of the stable region are extremely sharp. These limits are pH 4.5 and 6.5, and as the pH of a plain

maize paste lies within these limits its viscosity changes very little during an experiment.



With sago the result is not so definite. In Fig. 7 the stability is plotted against the pH of the pastes, a separate curve being drawn for each buffer salt. It is evident that the ions other than hydrogen exert a considerable influence on the stability. All the acetate mixtures for example have a low stability compared with citrate pastes of the same pH, and the most stable of any are the pastes made approximately neutral by the addition of caustic soda. In general, for any one buffer salt, the stability of the paste is greater the nearer the pH is to the region between 7 and 8, but it does not appear possible to obtain a very stable sago paste merely by buffering in this region. The points for the phthalate pastes do not fall on a smooth curve and are omitted from the figure.

For 3% farina pastes the region of high stability is a narrow one, and is in the neighbourhood of pH 4.5–5.0. The viscosity of a plain farina paste changes very rapidly with time, but the addition of salt leads to a considerable increase in stability, and the behaviour of buffered pastes is governed by the combined effects of the salt as such and of the hydrogen ion.

(b) Addition of Soap

The soaps used in the experiments described in this section were—

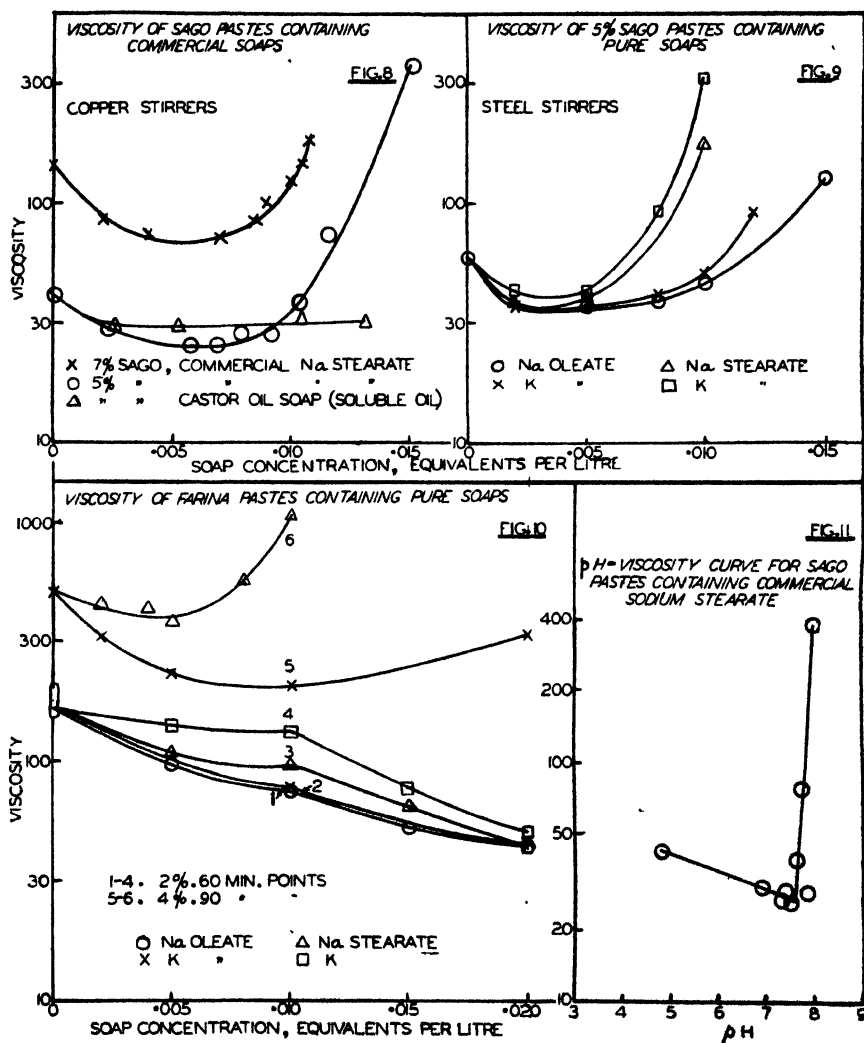
(a) A technical sodium stearate.

(b) Sodium stearate and potassium stearate, prepared by dissolving the theoretical amounts of Kahlbaum stearic acid in filtered solutions of the appropriate A.R. alkali hydroxide. Soap solutions were made up to be 0.1N concentration, and when required the soap gel was melted under a reflux condenser and the required volume of soap solution pipetted off.

(c) Sodium and potassium oleates, prepared in the same way as the stearates from B.D.H. redistilled oleic acid, with a combining weight of 281 as determined by titration.

(d) A trade sample of castor oil soap (soluble oil), supplied as a 20% solution. The main constituent of this material is sodium ricinoleate, and a 20% solution of this soap should be 0.625*N* with respect to alkali. The sample used was found on titration to be 0.66*N*, and this figure is employed to calculate the soap concentrations of the pastes (Table XIII, col. ii).

The experiments described in this section were made in two series—(1) Sago pastes, treated with the technical sodium stearate (*a*) or with the castor oil soap (*d*) (copper stirrers), and (2) sago and farina pastes containing the pure soap preparations (*b*) and (*c*) (steel stirrers). The results are given in Tables X–XIII and Figs. 8–15.



FIGS. 8-11

Table X

Viscosity of 5% Sago Pastes in the Presence of Sodium and Potassium Oleates and Stearates at 90° C. (Steel Stirrers)

Soap concentration Equivalents % on per litre paste	pH	η_{80}	$S_{90/80}$	Soap concentration Equivalents % on per litre paste	pH	η_{80}	$S_{90/80}$
<i>Sodium oleate—</i>				<i>Potassium oleate—</i>			
0	4.8	59.2	.82	.0020	7.5	37.2	.94
0.0050	8.0	38.0	.97	.0050	8.2	38.2	.98
0.0080	7.9	39.4	.96	.0080	8.1	41.2	.92
0.0100	8.2	45.7	.91	.0100	8.3	51.1	.92
0.0150	8.5	128	.68	.0120	—	91.2	.77
				.0150	—	very high	—
<i>Sodium stearate—</i>				<i>Potassium stearate—</i>			
0.0020	7.0	38.5	.92	.0020	7.9	43.7	.87
0.0050	7.7	40.6	.95	.0050	—	42.7	.92
0.0100	8.4	181	.83	.0080	8.1	93.3	.91
				.0100	—	337	.73

Table XI

Viscosity of 4% Farina Pastes in the Presence of Potassium Oleate and Sodium Stearate at 90° C. (Steel Stirrers)

Soap concentration Equivalents % on per litre paste	pH	η_{80}	$S_{90/80}$	$S_{115/80}$	Soap concentration Equivalents % on per litre paste	pH	η_{80}	$S_{90/80}$	$S_{115/80}$
<i>Potassium oleate—</i>					<i>Sodium stearate—</i>				
0	6.3	501	—	.74	.002	7.0	466	—	.82
0.002	7.1	324	.58	.91	.004	7.7	445	—	.85
0.005	7.6	232	.71	.96	.005	—	380	.61	.82
0.010	7.9	209	.76	.93	.008	—	566	—	.78
0.020	8.6	339	.85	.85	.010	8.5	1080	—	.84

Table XII

Viscosity of 2% Farina Pastes in the Presence of Sodium and Potassium Oleates and Stearates at 90° C. (Steel Stirrers)

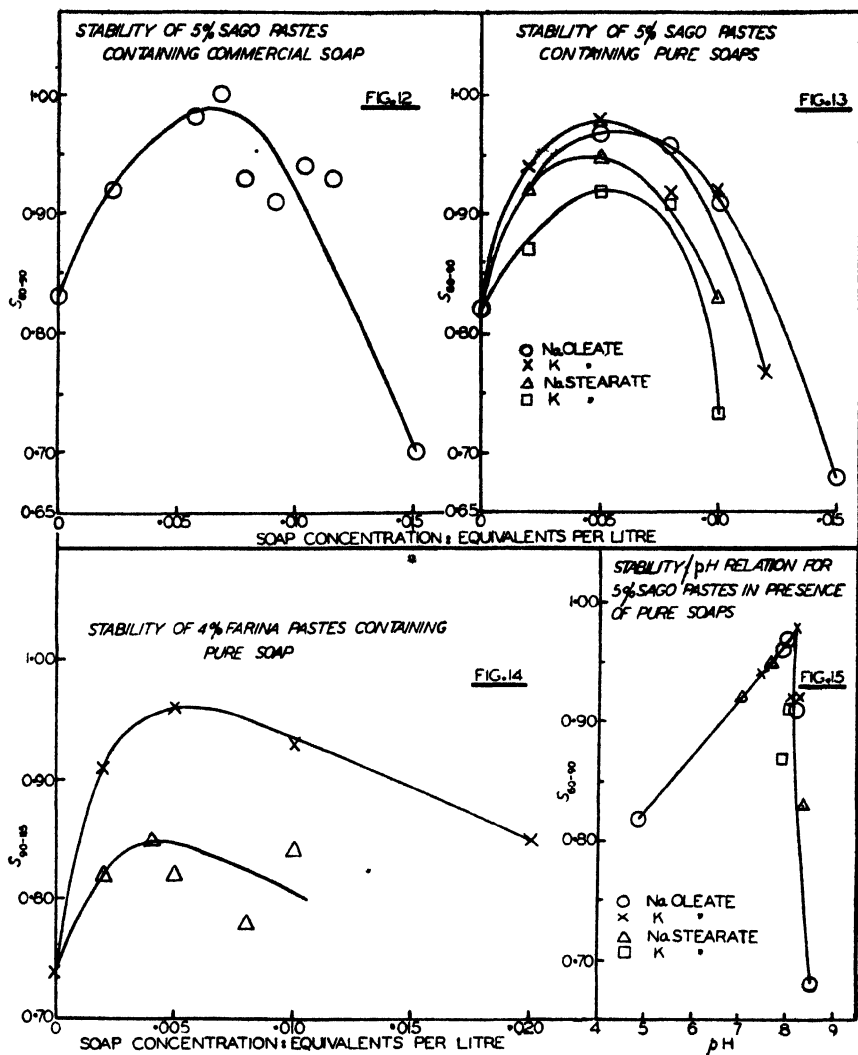
Soap concentration Equivalents % on per litre paste	pH	η_{80}	$S_{90/80}$	Soap concentration Equivalents % on per litre paste	pH	η_{80}	$S_{90/80}$
<i>Sodium oleate</i>				<i>Potassium oleate—</i>			
0	5.8	172	.73	.010	8.5	76.4	.84
0	5.7	202	.73				
0	—	166	.69				
0	—	180	.70				
0.005	8.3	97.3	.89	.020	46.2	.82	
0.010	8.7	75.7	.81				
0.015	9.0	52.7	.84				
0.020	>9	44.7	.82				
<i>Sodium stearate—</i>				<i>Potassium stearate—</i>			
0.005	7.6	108	.87	.005	8.3	141	.91
0.010	>9	95.9	.88	.010	>9	135	.91
0.015	>9	64.7	.85	.015	>9	79.4	.86
0.020	>9	44.5	.86	.020	>9	50.7	.88

Table XIII

Viscosity of 5% Sago Pastes in Presence of Castor Oil Soap (Sodium Ricinoleate, Soluble Oil) at 90° C. (Copper Stirrers)

"Soluble Oil" means the solution supplied, i.e. 20% solution of soap corresponding to a soap concentration of 0.66 N.

Soap concentration Equivalents per litre	Grams of "Soluble Oil" per 100 grams of paste	pH	η_{80}	$S_{90/80}$
0	0	4.8	41.2	.83
0.0026	0.39	7.4	31.3	.87
0.0052	0.78	7.6	31.3	.92
0.0105	1.58	7.8	33.1	1.00
0.0131	1.92	7.8	32.4	.92
0.0264	3.90	8.1	32.1	.95



FIGS. 12-15

Series (1) (Fig. 8)—The effect of a small addition of sodium stearate (less than 0.008 *N*) to a 5 or 7% sago paste is to lower the viscosity and to raise the pH . With increasing alkalinity the relation between viscosity and pH is very nearly the same as that described in the previous section for pastes between pH 4.8 and 7 (Fig. 11). As the additions of soap are increased, however, the viscosity passes through a minimum and subsequently rises rapidly. When made up to about 0.015 *N* in soap a paste is much more viscous than a paste of the same pH when no soap is present, and further addition of soap renders the paste too viscous to handle in the apparatus.

A small addition of castor oil soap (0.0026 *N*) causes an appreciable lowering of the viscosity, but further additions have scarcely any effect and the viscosity remains almost constant until the soap concentration is 0.0264 *N*, or 0.8% of the soap on the paste (Table XIII, Fig. 8).

Series (2)—The curves obtained for the pure soaps on the 5% sago and 4% farina pastes are very similar to those described under Series (1) (Tables X and XI, Figs. 9 and 10). The minimum viscosity occurs at a soap concentration of approximately 0.004 *N*, and is sharper than that obtained previously. The four soaps examined do not give coincident curves. Oleates produce a more rapid fall and a lower minimum viscosity than the stearates, and a less rapid rise when the minimum is passed; the curves for the potassium soaps lie a little above the curves for the corresponding sodium soaps.

When similar additions of soap are made to 2% farina pastes the viscosity continues to fall with increasing soap concentration, at least up to 0.020 *N*, and no sign of a minimum and subsequent rise has been observed in these pastes (Table XII, Fig. 10). The order of effectiveness of the soaps is the same as in the more concentrated pastes, potassium stearate causing the least fall of viscosity and sodium oleate the greatest.

Stability of the pastes in presence of soap.

The stability of sago and farina pastes is greatly improved by small additions of soap. In Figs. 12 and 13 the values of $S_{90/80}$ for sago pastes are plotted against soap concentration, and it is evident that the most stable pastes are obtained in presence of a soap concentration of 0.005 to 0.008 *N*. The results with farina pastes (Fig. 14) are less regular than with sago, but there is no doubt that an addition of soap does produce a real increase in the stability of the pastes. Castor oil soap also increases the stability of a sago paste (Table XIII).

pH Values of pastes containing soap.

Addition of soap to a starch paste considerably increases its alkalinity, but the *pH* of the paste remains much lower than that of a solution of soap of the same concentration in the absence of starch. For example, a solution of potassium oleate, 0.01 *N*, was found to have a *pH* of 9.5. A 5% sago paste (Table X) with the same concentration of soap had a *pH* of 8.3, a figure that may be compared with the value of 8.2 found for a 0.001 *N* soap solution. Even with the most concentrated soap solution employed (0.020 *N*) the *pH* of the paste did not exceed 9 for 4 or 5% pastes.

A very striking relation exists between the stability and the *pH* of the sago pastes containing soap (Fig. 15). With low soap concentrations, in the *pH* range 4.8–8, the stability rises in much the same way as in the pastes buffered within the same limits. Further addition of soap causes only a slight increase in *pH* but a very great loss of stability, quite unlike the corresponding buffered pastes.

(c) Addition of Tallow

When added to a 5% sago paste in quantity up to 10% of the weight of the starch, tallow causes no appreciable change in the apparent viscosity of the paste. When tallow is added along with soap, however, the effect of the soap may be considerably modified. Table XIV shows the effect of adding tallow incorporated as a pre-formed emulsion with soap to a 5% sago paste, so that the final soap concentration is 0.0122 *N* (0.34% on the paste). The results are erratic, and it was not found possible to obtain results of good reproducibility by any method of mixing the tallow with the paste, but it is clear that addition of tallow does appreciably lower the viscosity of the paste.

Table XV shows a similar result with a 7% sago paste and a soap concentration of 0.009 *N* (0.26% on the paste). When a lower concentration of soap

is employed, however, (0.004 *N*, 0.12%) the effect is reversed, and the tallow produces an increase in viscosity. A possible explanation of the behaviour of the tallow is that in forming the emulsion a part of the soap is removed from the sphere of action of the starch and cannot in consequence exert its specific effect on the viscosity. In low concentration soap lowers the viscosity, and a decrease in the availability of the soap due to the tallow should therefore lead to an increase in viscosity. With higher soap concentrations, at any point beyond the region of minimum paste viscosity, additions of tallow would be expected to lower the viscosity. Both these types of behaviour are observed and described above.

Table XIV

Effect of Tallow on the Viscosity of 5% Sago Pastes containing Sodium Stearate in 0.0122 *N* Concentration (0.34% on the Paste)

The soap and tallow were added together as a pre-formed emulsion to the starch paste (Copper stirrers).

% Tallow on dry starch	pH	η_{sp}	% Tallow on dry starch	pH	η_{sp}
0	—	66.1	10	8.0	36.1
5	8.1	41.7	10	8.0	40.3
5	8.1	61.7	15	8.1	30.7
5	8.0	57.5	15	8.1	32.4
5	8.2	49.0	20	8.0	30.1

Table XV

Effect of Tallow on the Viscosity of 7% Sago Pastes containing Sodium Stearate.

The soap and tallow were added together as a pre-formed emulsion to the starch paste (Copper stirrers).

Soap concentration 0.004 <i>N</i> (0.12% on paste)			Soap concentration 0.0090 <i>N</i> (0.26% on paste)		
% Tallow on dry starch	pH	η_{sp}	% Tallow on dry starch	pH	η_{sp}
0	7.4	75.9	0	—	100
5	7.0	88.1	5	7.5	79.4
10	6.7	83.6	10	7.3	75.0
15	6.4	88.1	10	7.5	74.1
15	6.4	88.7			
20	6.3	88.7			

(d) Neutral Salts

The effect of neutral salts on the viscosity of 5% sago pastes is small. The chlorides of sodium, calcium, zinc and magnesium, and also sodium sulphate, lower the viscosity slightly (Table XVI, Fig. 16). With the chlorides the smallest addition of salt (0.001 *N*) produces practically the full lowering, and there is very little change as the salt concentration is increased, although in the experiments with calcium chloride, where the salt was added up to 0.40 *N*, i.e. 2.22% on the paste, or 44.4% on the dry starch, the viscosity had again increased to about the viscosity of a salt-free paste. The stability of pastes containing salt is rather less than that of salt-free pastes, but this effect is also quite small.

Farina pastes on the other hand are extremely sensitive to salts (Table XVII, Fig. 16). Pastes of this starch prepared by the standard method used in this work are much more viscous than sago pastes of the same concentration, and much more difficult to manipulate on that account. When salt is added to the gelatinised starch, uniform mixing in the paste is not obtained at once, and the results are therefore not so regular as those obtained with sago. The viscosity-time curves show an inflection, which is most pronounced in the pastes with lowest salt concentration. This inflection is not

Table XVI

Effect of Salts on the Viscosity of 5% Sago Pastes (Copper Stirrers)

Salt concentration		η_{60}	$S_{90/60}$	Salt concentration		η_{60}	$S_{90/60}$
Equivalents per litre	% on paste			Equivalents per litre	% on paste		
No addition—		42.7	.84	<i>Calcium chloride</i> —			
<i>Sodium sulphate</i> —				0.02	0.11	37.8	.75
0.006	0.043	41.2	.79	0.20	1.11	38.0	.81
0.014	0.10	42.7	.79	0.30	1.67	39.8	.75
0.030	0.22	41.2	.79	0.40	2.22	45.7	.76
0.040	0.29	36.3	.79	<i>Zinc chloride</i> —			
<i>Sodium chloride</i> —				0.04	0.27	31.6	.68
0.001	0.006	39.8	.79	0.20	1.33	33.9	.69
0.010	0.058	39.8	.80	<i>Magnesium chloride</i> —			
0.040	0.23	36.3	.78	0.02	0.10	36.3	.80
0.080	0.46	39.8	.74	0.10	0.47	37.2	.76

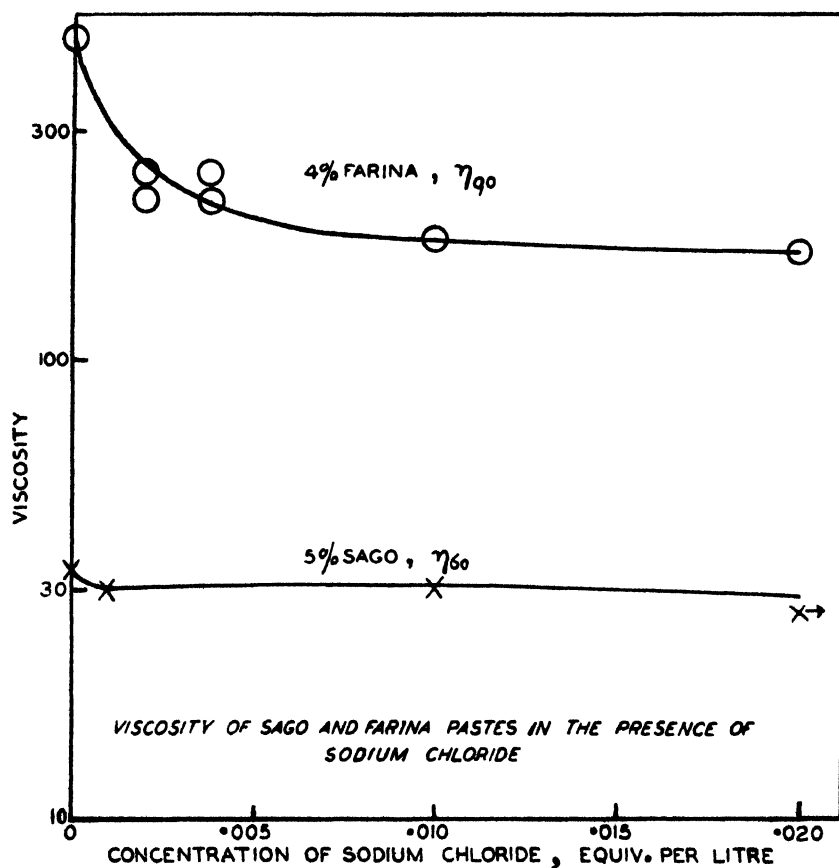


FIG 16

apparent in the curves obtained for plain pastes, and it is possible that it is due to incomplete mixing of the paste and the salt solution.

The 4% plain pastes were too viscous to measure accurately before 70 minutes heating, even in viscometer H, and therefore the comparisons are made between pastes heated for 90 minutes instead of the standard 60

minutes. It is evident from Fig. 16 that even the lowest salt concentration employed causes a marked lowering of viscosity, further addition of salt causing slight but appreciable further diminution.

The stability of farina pastes is increased by addition of salt. A 4% farina paste containing 0.010 equivalent of sodium chloride per litre (0.058% on the paste) has a stability value of 0.83 between 60 and 90 minutes, which may be compared with the value of 0.84 for a 5% plain sago paste and with 0.80 for a sago paste with the same salt concentration. Farina pastes containing salt are thus quite as stable as sago pastes.*

Borax, owing to its alkalinity, lowers the viscosity of sago pastes much more than neutral salts of the same concentration (Table XVIII). The viscosity falls with increasing borax content until a pH of about 7.5 is reached, whereupon further additions of the salt cause an increase in viscosity. The curve obtained is similar to that obtained by adding buffer mixtures to starch.

Table XVII

Effect of Sodium Chloride on the Viscosity of 4% Farina Pastes at 90° C. (Steel Stirrers)

Concentration of Salt		η_{90}	$S_{90/60}$	$S_{115/90}$
Equivalents per litre	% on paste			
0	0	501	—	.74
0.002	0.012	257	.68	.78
0.002	0.012	227	.63	.84
0.005	0.030	220	.81	.79
0.005	0.030	256	.96	.78
0.010	0.059	182	.83	.93
0.020	0.117	172	.88	.84

Table XVIII

Viscosity of 5% Sago Pastes containing Borax (Copper Stirrers)

Borax concentration % $\text{Na}_2\text{B}_4\text{O}_7$ in paste				Borax concentration % $\text{Na}_2\text{B}_4\text{O}_7$ in paste			
	pH	η_{90}	$S_{90/60}$		pH	η_{90}	$S_{90/60}$
0	4.8	43.7	.78	0.10	8.75	24.0	.81
0.01	6.95	25.1	.83	0.20	>9	27.5	.79
0.02	7.29	24.6	.81	0.30	>9	25.7	.80
0.02	7.37	24.3	.82	0.40	>9	28.2	.77
0.04	7.97	25.1	.81	0.81	>9	30.9	.79
0.06	8.85	25.1	.81				

(e) Mixtures of Starches

Two series of pastes were prepared with mixtures of sago and farina in various proportions, one series of pastes buffered with a phthalate buffer at pH 5, the other without any additions, the total starch concentration being 4% in each series (Tables XIX and XX, Fig. 17). In the unbuffered pastes those containing the highest proportions of farina were too viscous to handle in the apparatus. The two curves of viscosity against composition of the mixture are similar, the general level of viscosity of the buffered pastes being lower than that of the unbuffered, as would be expected from the behaviour

*The ash contents of the sago, maize, and farina used in this work were respectively 0.59%, 0.28% and 0.44%. These figures suggest that the relatively low sensitivity of sago towards additions of salts may be due to its initially high salt content. It was found, however, that although the ash content of the sago could be reduced by washing with water to 0.34%, the viscosity of a 5% paste of the washed starch was identical with that of the unwashed starch. The ash content of farina was reduced to 0.28% by washing. It must be concluded that the differences in viscosity behaviour between sago and farina are not due to differences in ash content.

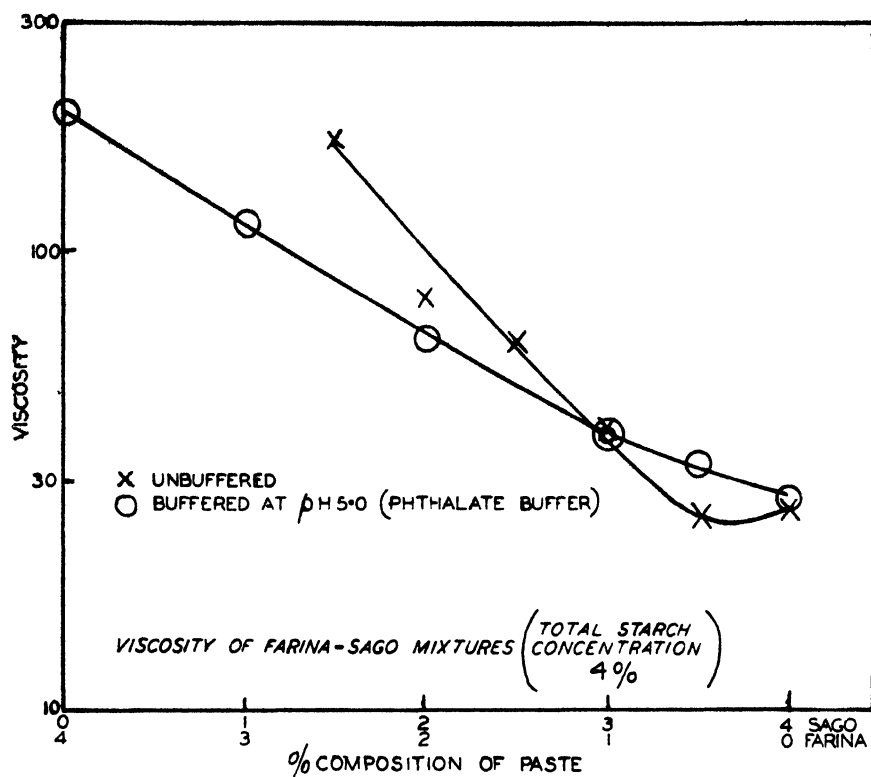


FIG. 17

of farina in the presence of salts. At high farina contents the curves appear to be linear, but at the other end there is a fairly pronounced curvature in both. The stability of these pastes is at a maximum when the composition of the mixture is in the proportion of three parts of sago to one of farina.

Table XIX

Viscosity of Sago and Farina Mixtures Buffered at pH 5.1. Total Starch Concentration 4% (Steel Stirrers)

Parts of Sago	...	...	4	3.5	3	3	2	1	0
η_{60}	...	...	28.8	35.1	39.8	39.8	64.3	115	200
$S_{90/60}$	...	...	.83	.86	—	.90	.90	.83	.85

Table XX

Viscosity of Unbuffered Mixtures of Sago and Farina. Total Starch Concentration 4% (Steel Stirrers)

Parts of Sago	...	...	4	3.5	3.0	2.5	2.0	1.5
η_{60}	...	...	27.9	26.3	41.2	63.1	79.4	178
$S_{90/60}$	...	...	.80	.79	.82	.77	.72	.63

(f) Effect of Metallic Copper and of Copper Sulphate

During the course of the work the copper stirrers were replaced by others of similar dimensions made from stainless steel. With these it was observed that the viscosity of a 5% sago paste was considerably higher than it would have been with the old copper stirrers. A recalibration of the apparatus revealed no cause for this change, which seemed therefore to originate in the material of the stirrers. Since a large amount of work had been done with copper stirrers it was desirable to ascertain to what extent the conclusions

might be affected by the type of stirrer used. Systematic experiments, the results of which are summarised in Table XXI, showed that with a new copper stirrer viscosities were obtained as high as those found with a steel stirrer, but that with successive pastes the copper led to a progressive fall to a constant value when some four or five preparations had been made. With a steel stirrer approximately constant values, considerably higher than those obtained with copper, were obtained from the first.

Table XXI

Viscosity of Unbuffered 5% Sago Pastes with Copper and Steel Stirrers

Paste No.	η_{60}	$S_{60/60}$	$S_{90/60}$	Paste No.	η_{60}	$S_{60/60}$	$S_{90/60}$
<i>Old copper stirrer—</i>				<i>Stainless steel stirrer—</i>			
68	43.7	.64	.79	607	61.0	.74	.86
<i>New copper stirrer—</i>				610	59.6	.73	.87
601	60.3	.66	.85	615	61.0	.73	.82
603	51.1	.63	.85	617	61.0	.74	.90
605	48.4	.65	—				
606	45.2	.67	.79				

As a check on the effect of the stirrer in the experiments on buffered pastes, a fresh series was made with a steel stirrer (Table XXII, Fig. 18). The shape of the pH-viscosity graph is much the same with either stirrer, but with steel

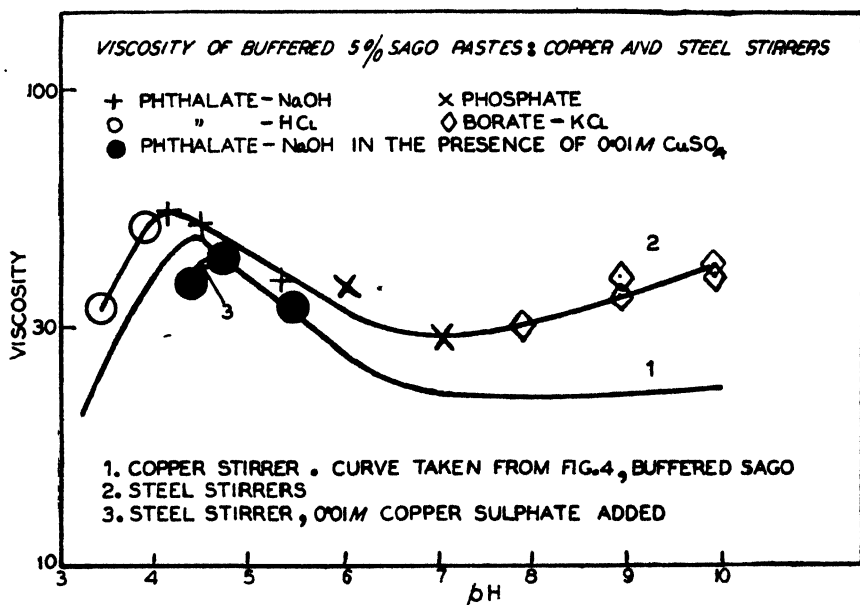


FIG. 18

the maximum is found at a slightly more acid pH, and the curve of viscosity slopes upwards slightly more steeply with increase of alkalinity beyond pH 7. The stability of pastes stirred by means of stainless steel is rather higher than that of those with copper. In the experiments with soap (Figs. 8 and 9) rather higher viscosities were observed in the steel-stirred pastes than in the others. The general conclusions are, however, unaffected by the fact that the earlier pastes were prepared in contact with metallic copper.

In some experiments copper sulphate was added to a series of pastes in an apparatus fitted with steel stirrers. The figures in Table XXIII show that the

added copper salt causes a fall of viscosity and a lowered stability in the 30–60-minute period. When the copper salt is added to buffered pastes the maximum viscosity occurs at a less acid pH than with either steel or copper stirrers without addition of the salt (Fig. 18, Curve 3).

Table XXII
Viscosity of Buffered 5% Sago Pastes (Steel Stirrers)

pH	η_{60}	$S_{90/60}$	pH	η_{60}	$S_{90/60}$
No addition—			Phosphate buffer—		
4.8	59.2	.82	6.00	38.9	.85
Phthalate buffer—			7.03	29.5	.85
3.45	34.8	.66	Borate—KCl buffer—		
3.88	51.3	.79	7.88	31.6	.85
4.14	56.2	.76	8.91*	39.8	.81
4.48	52.5	.83	8.93*	37.0	.86
5.34	32.7	.86	9.92*	40.6	.86
			9.90*	42.7	.85

* pH determined by glass electrode.

Table XXIII
Viscosity of 5% Sago Pastes in the Presence of Copper Sulphate
(Steel Stirrer)

Concentration of Copper Sulphate, moles per litre	η_{60}	$S_{90/30}$	$S_{90/60}$
0	60.3	.74	.82
0.0001	42.7	.62	.91
0.01	28.8	.66	.84

The effect of metallic copper is presumably due to solution of copper in the starch pastes. To investigate this, pastes prepared in copper and in glass vessels (boiling tubes) were evaporated to dryness and ashed, and copper was determined in the ash by the method of Brownsett, Farrow, and Neale.³ In two preparations made in copper vessels 3.98 and 3.71 milligrams of copper were found per 100 grams of dry starch. The corresponding figure for the glass vessel was 0.176 milligram. It is evident that the starch pastes prepared in contact with copper take up considerable amounts of the metal, suggesting that dissolved copper is responsible for depressing the viscosity of pastes prepared in contact with the stirrers of that material.

(g) The Viscosity of Pastes Heated for Long Periods or Under Pressure

It was not convenient to preserve a starch paste in the apparatus described in Section II (a) for more than a few hours. In order to make observations over a fairly lengthy period the pastes were transferred to resistance glass bottles in which air was replaced by nitrogen. These were suspended in the thermostat and samples withdrawn from time to time. Viscosity measurements were made in an instrument of the burette type, similar in principle to those employed in the determination of the fluidity of cotton in cuprammonium,⁶ and of such dimensions that the average shearing stress at the capillary wall was equal to 100 dynes per sq. cm. (see Section II (b)).

The changes of viscosity of a 5% sago paste stored in this way for seven days are shown in Table XXIV and Fig. 19. The viscosity continues to fall during the whole period, and although the rate of fall is slower in the later stages a constant viscosity is not attained. In Fig. 19 are also plotted some data for another 5% sago, and for a 5% maize paste, both stored in a similar manner, but without precautions to ensure the absence of oxygen. The fall of viscosity is considerably more rapid than when oxygen is excluded, but neither paste had reached a steady state in seven days. The viscosity of the maize

a higher soap concentration than 0.010 *N* the paste remained extremely viscous throughout the experiment, but accurate measurements could not be made.

Heating under pressure—The viscosity changes undergone by a paste during lengthy storage at 90° can be accelerated by heating under pressure. For example, the viscosity of a plain 5% sago paste, initially about 100, falls to a value of 5 during storage for one week at 90°, whilst a similar paste heated under a pressure of 40 lb. per sq. in. for four hours has a viscosity near 2. If the paste contains soap in 0.005 *N* concentration the initial viscosity is about 50, and this value is almost unchanged as a result of heating the paste in the autoclave.

(h) **Viscosity Measurements in Buffered Pastes immediately after Adding the Buffer Solution**

The experimental results described in the previous sections refer to pastes at least 30 minutes after the buffer salt is added. During this period the viscosities of the pastes have changed by amounts differing for each value of the *pH*. The differences between the observed viscosities and that of the unbuffered paste arise from the joint effects of the buffer mixture on viscosity level and on stability. It is desirable to separate these effects, and this could ideally be done by measuring the viscosity immediately after the buffer solution is added. In practice this is impossible, but a series of measurements

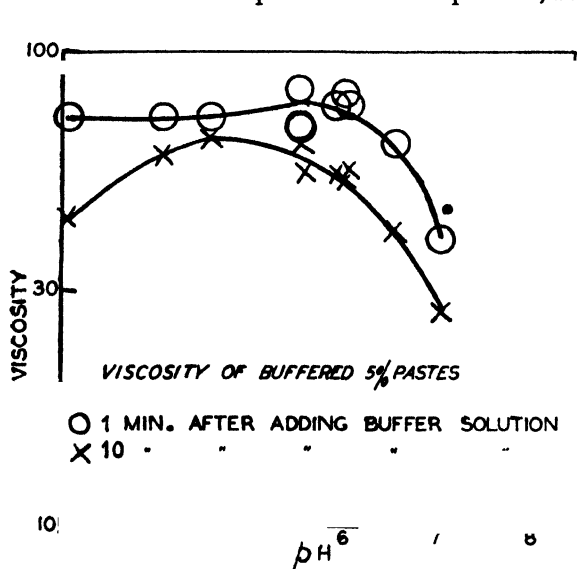


FIG. 20

was made one minute and ten minutes after adding the buffer to 5% sago pastes (i.e. 31 and 40 minutes from the commencement). The results are given in Table XXV and Fig. 20. For the one-minute measurement the viscosity is fairly constant between *pH* 3 and 6, the region in which the maximum of viscosity occurs in pastes 30 minutes after adding the buffer solution. Above *pH* 6 the viscosity falls. Ten minutes after the addition of the buffer, a well-defined maximum is found at *pH* 4.5–5.0.

Table XXV

Viscosity of Buffered 5% Sago Pastes measured 1 and 10 minutes after adding the Buffer Salt, that is, 31 and 40 minutes from the beginning (Steel Stirrers)

Buffer	<i>pH</i>	Log η_s		Buffer	<i>pH</i>	Log η_s	
		1 min.	10 mins.			1 min.	10 mins.
Phthalate ...	3.05	72.4	44.5	Phosphate ...	5.97	78.0	56.0
" ...	4.08	73.3	60.3	Phthalate ...	6.01	79.4	54.3
" ...	4.60	72.1	65.5	Phosphate ...	6.05	78.0	56.6
" ...	5.52	83.8	63.1	" ...	6.58	64.6	42.5
" ...	5.57	68.9	55.7	" ...	7.07	40.7	28.2

(j) Reducing Power of Starch Pastes

Measurements of the reducing power of the pastes used for viscosity determinations were made by the copper number method described by Fargher and Probert.⁷ No significant reduction of copper could be observed with any of the pastes after the normal heating period of from one to two hours, unless the paste was more acid than pH 3. Even after 24 hours at 90° pastes at pH 4 have only a barely appreciable copper number, and less acid pastes are non-reducing. Table XXVI shows the change of copper number with time in a series of sago pastes buffered at various pH values, stored at 90° in an atmosphere of nitrogen in resistance glass bottles. The table indicates that prolonged heating of a neutral or faintly acid paste is necessary before any reducing power is exhibited.

Table XXVI
Copper Numbers of Buffered 5% Sago Pastes at 90° C.

pH of paste	Time of Storage, days				
	2	3	4	7	11
3.1	17.2	25.0	34.9	>50	—
4.1	0.55	2.3	2.6	5.43	8.84
4.7	0.07	0.04	0.34	0.39	0.77
5.0	0	0.02	0.09	0.08	0.17
7.0	0	0.04	0	0	0.11

Similar results were obtained with a plain unbuffered paste stored in a similar manner (Table XXIV).

In order to obtain comparable results by the method of Fargher and Probert it is essential to employ exactly 0.250 gm. of starch in the determination, as results based on other weights of starch with the same quantity of oxidising agent do not give the same copper number. During the present work it appeared desirable to investigate the relation between reducing power and amount of starch in more detail. A number of pastes with appreciable reducing power were prepared by different methods—

- (a) Heating in an autoclave for various times at about 40 lb. per sq. in.
- (b) Heating for long periods at 90° in closed bottles containing nitrogen.
- (c) Treatment with sulphuric acid of suitable concentration for short periods at 90° .

The reducing power of the preparations was measured by Fargher and Probert's method, a series of different weights of each sample being employed.

Some of the results obtained are plotted in Fig. 21 as weight of copper reduced (corrected for a blank error equivalent to 0.25 milligram, determined in the absence of starch) against the amount of starch employed in the experiment. Some data for dextrin, given by Fargher and Probert, and for glucose, given by Fargher and Lecomber,⁸ have been recalculated to a similar basis, and are also plotted in Fig. 21. All the graphs, with the exception of the upper portion of the glucose curve, are straight lines. They do not pass through the origin, but make a positive intercept on the horizontal axis.

The significance of this intercept is that a definite "threshold" amount of material must be present before any reduction of copper takes place at all. This has been verified by separate experiments with amounts of starch or glucose less than the threshold amount (Table XXVII). For glucose the threshold amount required is 0.0014 gm. and for the particular modified starch to which Table XXVII refers it is 0.09 gm.

Table XXVII

Reducing Power, by the Copper Number Method, of Small Amounts of Modified Starch and of Glucose

Blank correction=apparent weight of copper reduced in absence of carbohydrate, 0.25 milligram

Modified Starch		Glucose	
Wt. of Starch gm.	Wt. of Reduced Copper (corrected), milligrams	Wt. of Glucose gm.	Wt. of Reduced Copper (corrected), milligrams
0.027	0.05	0.00025	0.03
0.053	0.10	0.00050	0.05
0.080	0.12	0.00075	0.12
0.106	0.86	0.00100	0.08
0.160	2.59	0.00150	0.79
0.266	7.55	0.00250	2.92

These experiments indicate that the absence of apparent copper reducing power cannot be taken as evidence that glucose is absent from a solution, or that a starch paste has not undergone some hydrolysis.

§

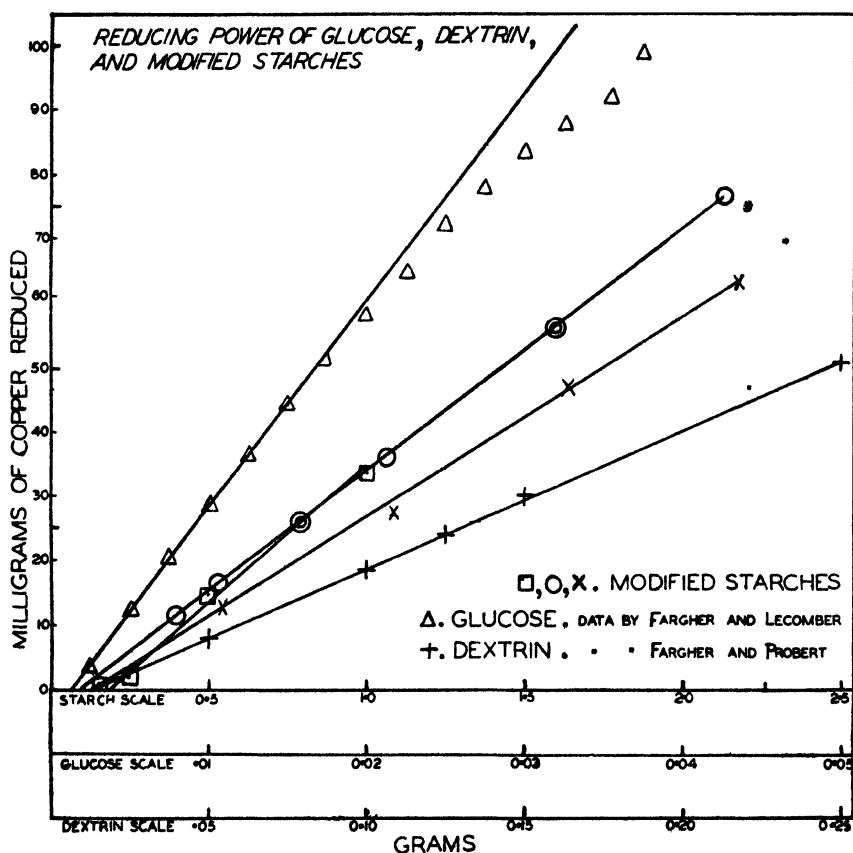


FIG 21

(k) Addition of Reagents before Gelatinisation of the Starch

In two series of experiments, technical sodium stearate and sodium sulphate respectively were added to the starch before heating began, and the starch

was thus gelatinised in the presence of the added material. Viscosity measurements were made at 15-minute intervals in the usual manner.

Sodium stearate (Table XXVIII, Fig. 22)—When granular starch is suspended in solutions of sodium stearate of concentrations up to 0.003 *N* to give a 5% paste on heating, as described above, the course of the viscosity-time curve is similar to that for a plain paste, except that the general level of the curve is higher, and the fall of viscosity with time is less rapid. At slightly higher soap concentrations than 0.003 *N* the pastes have a maximum viscosity at some definite time. The maximum viscosity attained is approached more slowly, and has a lower value, the higher the soap concentration, and at a higher concentration than 0.005 *N* the viscosity of a paste continues to rise slowly, without attaining a maximum, for at least two hours, which was the normal duration of these experiments. In two experiments with 0.01 *N* soap the viscosity increased at a steady rate for more than five hours. In those pastes which reached a maximum viscosity in moderate times the subsequent rate of fall of viscosity was slow.

Table XXVIII

Effect of Sodium Stearate, added before Gelatinisation, on the Viscosity of 5% Sago Pastes (Copper Stirrers)

Soap concentration		<i>pH</i>	η_{sp}			
Equivalents per litre	% on paste		30 mins.	60 mins.	90 mins.	
0	0	4.8	67.8	43.7	34.3	
0.0011	0.03	6.4	135	77.6	58.2	
0.0024	0.07	6.7	182	104	86.1	
0.0031	0.09	7.4	300	193	159	
0.0037	0.105	7.6	376	302	256	
0.0046	0.13	7.7	415	385	355	
0.0054	0.155	7.6	302	275	—	
0.0062	0.18	7.7	224	246	213	
0.0072	0.205	7.6	251	335	363	
0.0087	0.25	7.6	45	92.5	116	
0.0125	0.36	8.1	27	38	41	

The viscosity values at 60 minutes, read from the viscosity-time curves (η_{60}) are plotted against soap concentration in Fig. 22. The curve shows a maximum viscosity at about 0.0040 *N*, with a rapid fall of viscosity at higher concentrations than this.

The low viscosity of the pastes of high soap content was due to the fact that in them the starch was not completely gelatinised although the pastes had been heated at 90° for two hours, and in two experiments for five hours. On cooling, the pastes separated into two layers, the upper layer containing starch in solution and the lower consisting of swollen but still recognisable granules. Such undispersed granules could be seen under the microscope in all the pastes with a higher soap concentration than 0.003 *N*, although the pastes of high viscosity appeared to be normal in other respects. In all the pastes containing soap the starch could be completely dispersed by heating to 100° for a short time.

pH of the pastes—The course of the *pH* variations with soap content is also shown in Fig. 22. A plain sago paste has a *pH* of about 4.8, and additions of soap make the pastes progressively less acid until at 0.003 *N* the *pH* has a value of about 7.6. Larger additions of soap up to 0.009 *N* cause no significant alteration of this value, and only when the concentration of soap is made up to 0.0125 *N* does the *pH* rise to 8.1.

Table XXIX

Effect of Sodium Sulphate, added before Gelatinisation, on the Viscosity of 5% Sago Pastes (Copper Stirrers)

Concentration of Sodium Sulphate Equivalents per litre	% on paste	30 mins.	η_s 60 mins.	90 mins.
0	0	67.8	43.7	34.3
0.50	3.55	164	79.4	54.9
1.00	7.1	285	174	111
1.20	8.5	977	596	324
1.60	11.4	295	347	251
1.80	12.8	104	137	132
2.00	14.2	10.1	13.7	15.1

Sodium sulphate (Table XXIX, Fig. 23)—Incorporation of sodium sulphate into sago pastes before gelatinising gives rise to a family of curves similar in general shape to that described above for sodium stearate. For corresponding types of effect, however, a much higher concentration of sodium

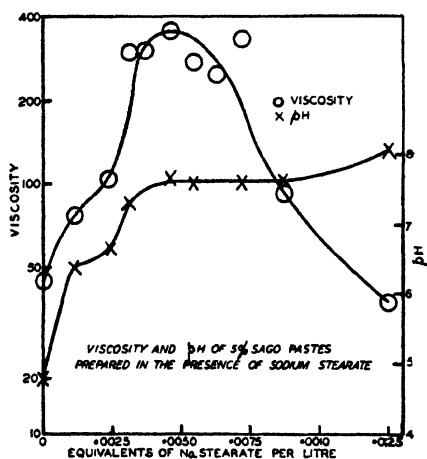


FIG 22

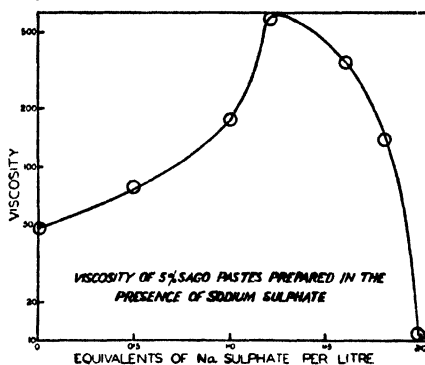


FIG 23

sulphate is required. For example, the attainment of maximum viscosity at 60 minutes requires a concentration of 1.2 equivalents of sodium sulphate per litre, compared with 0.004 equivalent of soap. The low viscosity at high salt concentrations is again due to failure of the starch to gelatinise completely, and with 2*N* sodium sulphate, the highest concentration employed, the starch is only slightly swollen at 90° C.

IV—DISCUSSION OF RESULTS

None of the measurements described in this paper has been made on a system in equilibrium, and it is necessary in the first place to discuss the changes that take place on preparation, storage, and measurement of the pastes. Three types of change are recognisable—

(1) The rise of viscosity brought about by the swelling and disruption of the starch granules.

(2) A fall of viscosity associated with mechanical agitation.

(3) A fall of viscosity observed on storage at rest or under conditions of mechanical agitation. This fall is ascribed to hydrolytic disruption of chemical linkages in the originally existing starch paste.

First type—An initial rise of viscosity is observed when the relatively non-viscous suspension of starch granules is heated to a temperature sufficient

to produce gelatinisation.¹⁵ In the present experiments this rise is recorded for maize starch only, which for some reason not at present understood appears to gelatinise less rapidly than sago or farina, and to be subject to a less rapid subsequent fall of viscosity. The result is that the viscosity of a maize paste stirred at the standard rate of 500 r.p.m. passes slowly through a maximum value, beginning to diminish only after 40 minutes' storage at 90° C. With sago and farina the initial rise of viscosity in the method of preparation employed is more rapid, and the maximum is reached and passed before the first observations are made (Fig. 3).

Second type. Effect of mechanical agitation—It has been shown that increasing the rate of stirring of a paste leads to a lower viscosity. It is conceivable that where copper stirrers are employed this is due to some extent to increase of contact of the starch with this catalytic material, with consequent increase of hydrolysis (see below), but the principal effect of stirring is probably the disentangling of the interlocked fragments resulting from the hydrolytic fission of the molecules. In support of such an explanation is the fact that a paste that has a viscosity characteristic of a slow stirring rate falls rapidly in viscosity on being subjected to rapid stirring, till it reaches the state it would have had at the same time if it had been rapidly stirred from the first. Mechanical agitation also hastens the attainment of maximum viscosity, probably by assisting in the disintegration of the starch granules and so releasing their parts from structural stresses that retard swelling and disintegration.

Third type. The diminution of viscosity with age—After the attainment of a maximum the viscosity of all pastes falls off continuously, and this fall is maintained for as long as the paste is preserved hot, whether stirred or unstirred. For pastes stored for long periods the considerable fall of viscosity that is observed is accompanied by a development of reducing power, which increases as storage is prolonged. This production of reducing power (measured by copper number) is a characteristic result of the acid hydrolysis of starch. It is now generally accepted that starch consists of chains of glucose residues, linked by α -glucoside bonds.^{10,14} In the presence of acid these are hydrolysed more or less rapidly, and reducing groups are developed. At the same time the molecular dimensions are reduced and the viscosity falls.

It is suggested that this account of the well-recognised phenomena of acid hydrolysis of starch is also applicable to the slower but equally definite phenomena that occur in the pastes of much lower acidity such as have been employed in this work. An argument against this is the failure to find any evidence of reducing power in some preparations that have suffered considerable fall of viscosity. It has, however, been shown that an equal failure may occur in certain circumstances in solutions containing quite definite amounts of glucose (see Table XXVII). The apparent absence of reducing power can therefore not be regarded as conclusive evidence that no hydrolysis has occurred, and the major part of the change that occurs in a plain starch paste is now attributed to acid hydrolysis of the same kind as, but differing continuously in extent from, the readily recognisable hydrolysis occurring when more massive quantities of acid are introduced into a starch preparation. Certain consequences of this hypothesis will be tested in the following section of this discussion.

The True pH-Viscosity Relation for Unhydrolysed Starch

There is little doubt that the curves presented in this paper show the practical relationship between acidity (pH) and viscosity for pastes of different ages. It has been pointed out that all measurements have been made on materials that are undergoing change, and that the rate of this change is greater for the more acid pastes. It is conceivable therefore that the low viscosity of these pastes is primarily attributable to their rapid fall from a condition of high viscosity. Measurements made on a series of pastes of the same age at the moment of mixing with a range of buffer solutions would ideally show differences of viscosity arising from the momentary equilibrium of starch with the buffer solutions. Such ideal instantaneous measurements are unattainable, but approximations to them are given by the series of observations at one minute and ten minutes after mixing (Table XXV, Fig. 20). The earlier the measurement the less pronounced is the maximum in the viscosity curve on the acid side, and it is extremely probable that in the initial state the curve rises steadily and fairly steeply to the most acid state investigated.

In pastes of the same acidity the fall of viscosity is more rapid with copper stirrers than with steel, owing presumably to a catalytic effect of copper on the hydrolysis. The viscosity maximum should therefore occur at a less acid pH with copper stirrers and this is what has been found (Fig. 18, curves 1 and 2). When hydrolysis is still further accelerated, by adding copper sulphate to the pastes, the maximum moves still further to the alkaline side.

The modification of the curve on the alkaline side by extrapolation to zero time has not been investigated, but there is some evidence that in freshly mixed pastes the viscosity rises with increasing alkalinity. There is, for example, the fact that a definite slope is introduced by using the non-reactive steel stirrers instead of copper (Fig. 18). It seems probable therefore that the primary curve for the viscosity of pastes freshly mixed with buffer solutions is of simple form, the viscosity falling from its highest value in the most acid region to a minimum between pH 6 and 8 and rising again as the alkalinity increases. Our knowledge of the physical chemistry of starch and the definition of the curve itself are both insufficient to justify further discussion at present.

The Practical pH-Viscosity Curve. Stability

Starch pastes used industrially for sizing cotton warps are commonly employed at the natural pH of the starch. For sago this is at the viscosity maximum at about pH 4.8. An unfavourable feature of this region is the fact that the rate of change of viscosity with time is high, and that in consequence freshly prepared pastes are liable to fall off in viscosity to an inconvenient extent while in use. The relatively high viscosity at pH 4.8 (i.e. in unbuffered sago) may be considered desirable but, if not, some treatment to make the paste more alkaline would lower the viscosity and increase the stability. It is, however, uncertain whether exactly neutral or slightly alkaline sizing pastes are advantageous or desirable. It is well known that alkalinity darkens the colour of sago size, whilst there is no agreement on the relative advantages of sizing with pastes of high or of low viscosity. If, as seems probable, low viscosity offers more favourable conditions for the manipulation and application of size, it might well be worth while to bring sago pastes to the neutral point by suitably graded additions of some buffer salt such as sodium phosphate. The possible use of soap for this purpose is discussed below.

Maize starch similar to the sample employed in these experiments could be used with advantage in the unbuffered state, since at its natural pH it is very stable in viscosity. This high stability conceivably arises through some balance between the gelatinising process, which as noted above, is very slow for maize, and the normal hydrolysis dependent on pH .

For farina as used in the warp sizing industry, control of pH is of relatively minor importance, the whole character of the operation being determined by the high initial viscosity and rapid change with time. It is most stable when buffered at its natural pH , and, as has been shown, any addition of salt made with the object of controlling its acidity brings about an immediate fall from the high viscosity that characterises the unbuffered starch.

The Effect of Soap on Viscosity

When raw starch is suspended in a soap solution and the material is heated, gelatinisation is delayed, and if sufficient soap is present may even be prevented unless the paste is heated to temperatures higher than the boiling point. When soap is added in small amounts to an already formed starch paste, the normal ageing changes are retarded, and the stability is increased to an extent altogether beyond any effect arising from the small changes in pH that accompany the addition.

Both these effects suggest that the soap is reacting with the starch in such a way as to prevent access of water to the points that are active when swelling occurs or to those susceptible to acid hydrolysis. If such a compound of soap and starch is formed it might be expected to have a branched structure in which the quite considerable chains of the soap molecules do not fall in with the prevailing arrangement that determines the mechanical condition of the starch water mixture. A considerable increase in the resistance to disturbance would result if such a compound were formed, and this is what is observed.

This reaction of starch with soap is of some practical importance. Soap is employed in size pastes and in rather larger concentrations in pastes used for pasting cops in spinning, or in finishing. For these latter purposes the proportion of soap may be sufficient to raise the gelatinisation temperature of the starch to such an extent that the mixtures are imperfectly gelatinised, and irregular results are obtained. With such mixtures better results are in general obtained by adopting a procedure similar to that employed in these experiments, adding the soap to the paste after it has been heated sufficiently to ensure complete gelatinisation. This precaution is generally unnecessary in sizing pastes when they are boiled by open steam. In these pastes the advantage of the use of soap probably lies in its powerful effect in checking the fall of viscosity of the size during use.

The Effect of Salts on Viscosity

The addition of moderate quantities of soluble salts to a starch paste diminishes the viscosity in a manner similar to that which has been observed for sols of gum arabic,^{16,17} for soluble starch¹¹ or agar.¹³ The fall of viscosity has been ascribed either to a diminution of hydration of the colloid brought about by the electrolyte, or to a diminution of its electro-kinetic potential relative to water. There are not sufficient data on either hydration or potential of starch to permit of detailed discussion of the effect at present. One anomaly may, however, be noted. The viscosity of sago pastes changes more rapidly with time when salt is added, but the reverse is true for farina. It is unlikely that an addition of salt would increase the rate of hydrolysis of

sago while retarding that of farina, and it seems probable that some other factor than hydrolysis is responsible in part for the changes in viscosity of farina pastes.

Farina is, moreover, distinguished by the extreme sensitivity of the viscosity of its pastes to small additions of electrolytes. It is prized as a sizing agent on account of its high viscosity, but this is offset by its low stability. If high viscosity is aimed at, farina pastes should be made up with pure water and without any addition of electrolytes. On the other hand, if a stable size containing farina is required it may be advantageous to add a small quantity of a salt such as sodium sulphate to the mixture in order to ensure that sufficient electrolyte is present to bring about the characteristic initial drop of viscosity that makes for insensitivity and stability in a farina mixture.

Part of the experimental work was done by Mr. R. O. Scott, B.Sc.

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CORRIGENDUM

"31—FIBRE GROWTH PHASES IN A SAMPLE OF AUSTRALIAN MERINO WOOL"

By J. E. NICHOLS
(Wool Industries Research Association)

Attention is drawn to a misprint which occurred in the above paper in the September issue of this *Journal* on page T339, fifth line from the top. This should read—

$$\text{"the diameter changes } \propto \frac{1}{\sqrt{F}} \text{"}$$

and not as printed.

THE JOURNAL OF THE TEXTILE INSTITUTE TRANSACTIONS

36—A PHOTOGRAPHIC STUDY OF STRETCHING, TWISTING, AND SWELLING OF WOOL AND OTHER FIBRES

By P. W. CUNLIFFE, Ph.D., F.I.C., F.R.P.S.

(Wool Industries Research Association)

INTRODUCTION AND SUMMARY

The object of these investigations is to study the visible damage in structure which occurs when a fibre is stretched or twisted in aqueous medium, or when it is swollen in sodium sulphide solution. Kronacher and Lodemann¹ have followed the changes which occur on stretching wool fibres, employing the cinematograph and the microscope. They reproduce photographs enlarged from the film, and these show that the scales are elongated while the diameter of the fibre is decreased. They also give examples of the different types of break which may occur.

In the preliminary part of the present work similar results have been obtained, using a 16-mm. cinematograph camera. The enlargements made from this film, in common with those of Kronacher and Lodemann, are not as sharp as is desirable, and consequently the remainder of the work has been done by "still" photography, obtaining directly negatives of the required dimensions. It is necessary by this method to stop the stretching or twisting process whilst the photograph is taken, but the interval has been reduced to 30-60 seconds by employing an intense source of light (a Pointolite lamp) and rapid panchromatic plates.

In the experiments on twisting, one end of the fibre is held whilst the other is rotated until finally the fibre breaks. The amount of twist is, therefore, much greater than occurs in manufacturing processes. In a medullated fibre, the air is compressed to a small volume, or possibly to some extent forced towards the untwisted portion, as is shown by the fact that the transparency of the medulla is greatly increased on twisting, but decreases again on untwisting. The air is sometimes expelled from the fibre through cracks or spaces in the wall.

A weak solution of sodium sulphide causes wool and other fibres to swell to some four or five times their original diameter. The medulla, when present, becomes transparent, showing that the air spaces have been filled. The walls of the medulla are apparently highly resistant to the sulphide solution, since this portion of the fibre swells to a very small extent only. The swelling process has been applied to an investigation of the distribution of pigment in coloured fibres. Such inquiries have always been impeded by the low transparency of black or dark fibres, but these may be readily photographed in detail after swelling. Fine particles of pigment are distributed throughout the cortex, but the medulla, when present, contains large aggregates of pigment.

Negro hairs swell in different ways, according to their nature. With the more brittle ones, it is possible for the whole of the interior of the hair to come away, having a transparent cuticular envelope on which the scale markings are clearly visible.

STRETCHING OF WOOL FIBRES

The fibre is attached to the midpoint of one of the longer sides of an ordinary glass slip, which is placed on the mechanical stage of the microscope. The fibre is passed across the slip and fixed in a hole in a metal rod which can be rotated through reduction gearing having a ratio of about 60:1. (Fig. 1). The fibre is stretched slowly by winding the gearing, and its progress is followed visually, a chosen portion being kept in the field of view by means of a backward movement on the mechanical stage.

Unsatisfactory results are obtained when the fibre is mounted in a medium and covered by glass, but good definition is given by the method of Manby². In this method, a small amount of medium (usually 25% glycerine in water, in this work) is put on the fibre by means of a small brush. The medium quickly runs off the upper surface and embeds the lower half of the fibre, so that when the upper scales are in focus, there is no interference from the lower ones.

The source of light is a Pointolite lamp, and both axial and oblique illumination have been used. Axial illumination renders the edges of the scales as sharp lines, but oblique lighting causes the scales to cast shadows and thereby gives the impression of relief. The objectives used have been 16-mm. and 8-mm. apochromatic, in conjunction with compensating eyepieces of various magnifications. Rapid panchromatic plates and a green filter have been used.

Results

Two series of photographs which illustrate the different stages of stretching of wool fibres, are shown in Figs. 2 and 3. The fibre used in the front series is somewhat irregular and the flattened portion selected is about three times the average width; this has been done because the scales are particularly well defined at this point. The illumination is axial, and the dark mottled appearance of Fig. 2 is due to traces of medulla. Oblique illumination has been used for Fig. 3.

As the fibre is stretched, its width decreases considerably, although accurate measurements cannot be made from these photographs, owing to the loss of definition at the edges due to the small depth of focus. The scales are distorted and stretched with the bulk of the fibre, and since they return to their original form after the fibre has broken (Fig. 3), i.e. they are highly elastic.

Near the sharp outline of the edges of the scales of some fibres may be seen a fainter line (Fig. 2) which presumably indicates the limit of the under edge of the scales. This second line is more prominent in the stretched fibre. In Fig. 2 B and C, there are lines near the top of each photograph which are not visible on the unstretched fibre (A), but it does not appear to be safe to conclude that these have been formed by the stretching process, since, as stated, stretching makes more clear the lines already present. In Fig. 3 there is no indication of the development of cracks in the scales on stretching.

TWISTING OF WOOL FIBRES

The fibre is fixed in a small Polykeit apparatus attached to the microscopic stage, and passes through a small glass trough which contains a liquid medium and which is covered by a thin glass. The medium ordinarily used has been a mixture of equal parts of glycerine, alcohol and water, and sometimes 25% glycerine in water. The apparatus is so constructed that the fibre is raised about 2.3 cms. above the stage and this renders the use of the ordinary substage condenser impossible. The difficulty has been partially overcome by substituting a $1\frac{1}{2}$ -in. objective for the condenser, although this arrangement does not give critical definition.

Results

A typical example of the appearance of a crossbred fibre during the course of twisting is shown in Fig. 4. This particular fibre had been in the glycerine-water-alcohol mixture for three days before twisting and consequently was very plastic. As the fibre is twisted, its diameter is reduced progressively. The medulla becomes more transparent, revealing the usual irregular-shaped cells, an effect which appears to be due to compression of the medullary air. With some fibres, and more particularly with kemp, the twisting process forces the air through the fibre wall, and if the fibre is in a liquid medium, the air bubbles can readily be seen. The ribbon-like fibre shown in Fig. 5 illustrates such an effect, the dark circles being the air bubbles, whilst the increase in transparency again demonstrates the loss of air.

SWELLING OF FIBRES AND HAIRS IN SODIUM SULPHIDE SOLUTION

It is well known that wool fibres swell and become more transparent when placed in a solution of sodium sulphide. In this state the fibres reveal structural details which are not apparent in the normal condition, and the following investigations have made use of this property. The fibres which have been investigated include unpigmented, partially and heavily pigmented wool fibres, and negro hair, whilst the results bear mainly on the constitution of the medulla and the distribution of pigment in coloured fibres and hairs.

The technique consists simply in placing the fibre in a slide in contact with sodium sulphide solution, covering with the usual glass and taking photographs at intervals. Since the fibre swells continuously, rapid panchromatic plates and an intense illuminant (Pointolite lamp) are used, in order to reduce the time of exposure to a minimum.

Results

A typical crossbred fibre swells fairly uniformly for a time (Fig. 6), but sometimes begins quite rapidly to assume a bead-like or bulging form, the fibre curling at the same time. The medulla, where present, usually swells slightly but not nearly in the same ratio as the total width of the fibre, and may actually decrease again, although the total width of the fibre continues to increase. The walls of the medulla must, therefore, be of a particularly resistant nature, a conclusion which is confirmed by the twisting experiments, in which the medulla is seen to preserve its form in spite of the large forces involved.

The swelling of pigmented fibres in sodium sulphide solution proves a valuable method in determining the manner in which the pigment is laid down in the fibre. The swelling of a black lamb (Southdown \times Blackface)

fibre is typical (Fig. 7), the photographs of which have been taken through a deep red filter (Wratten "F"). The medulla contains a considerable number of large pigment aggregates which retain their form, even when the fibre is almost completely disintegrated. Smaller particles of pigment also occur in the cortex, the strands of the disintegrated fibre being dotted throughout their length. Partially pigmented fibres show the same type of distribution (Fig. 8). The cuticle may leave the cortex on swelling, and is seen to be quite free of pigment (Fig. 7B). This is demonstrated very clearly with negro hair in the results to be discussed. The pigment appears, therefore, as large aggregates in the medulla, as smaller ones in the cortex, and not at all in the cuticle.

SWELLING OF NEGRO HAIR

The swelling which negro hairs undergo in sodium sulphide solution assumes several forms, depending on the nature of the hair. The first type is similar to that given by wool fibres. In the second type the cuticle swells excessively and irregularly, and produces a transparent bead-like form (Fig. 9). The third type is remarkable and has been obtained only with brittle hairs (Fig. 10). In this the cortex becomes detached from the cuticle, which is left as a transparent envelope on which are visible the scalar markings. In one fibre (Fig. 10A) the whole of the interior wormed its way out through a transverse crack leaving the cuticular envelope intact.

Mr. W. T. Tyas has given valuable assistance with the photography.

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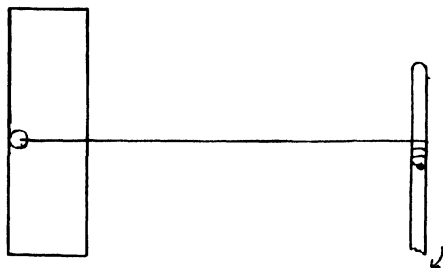


FIG. 1



A

B

C

FIG. 2

Photographed with axial illumination

A Unstretched

B Stretched by 27%.

C Stretched by 30%.



FIG. 3
The topograph of with oblique illumination
A Unstretched
B Stretched by 1%
C Stretched by 3%
D Stretched by 4%
E Recovered fibre after break in another portion

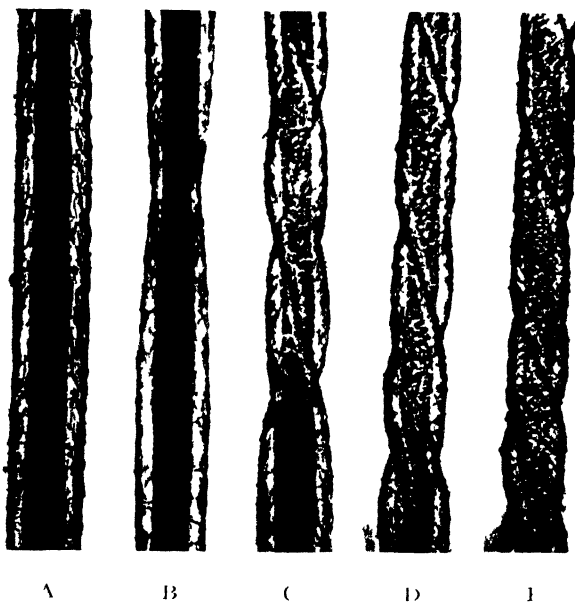


FIG. 4
A Untwisted
B With 15 turns
C With 31 turns
D With 54 turns
E With 90 turns

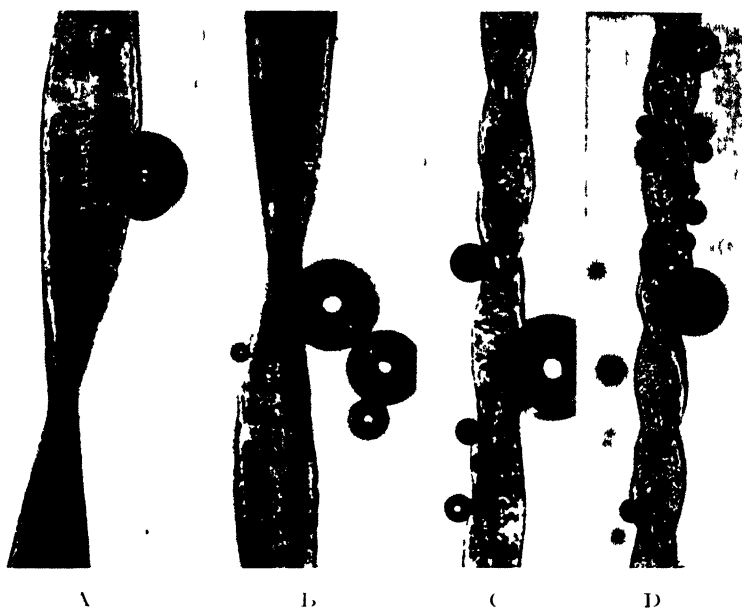


FIG. 5

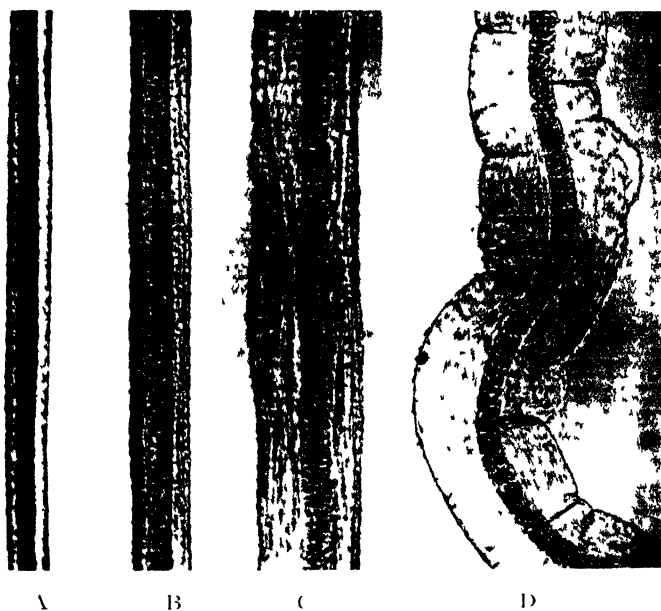


FIG. 6

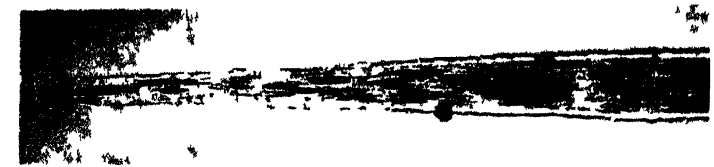
A In water
In 2% sodium sulphide solution for
B 10 mins
C 20 mins
D 45 mins



A



B



C



D

117
 A In sodium sulphide solution for 10 min
 B In sodium sulphide solution for 45 min
 C In sodium sulphide solution for 1 h
 D In sodium sulphide solution for 2 h



FIG. 8

In sodium sulphide solution for 25 mins (- 87)



A

FIG. 9

B

A Negro hair in water (- 93).

B After 32 mins in sodium sulphide solution (- 93)



A

FIG. 10

B

Negro hairs after 1 hour in sodium sulphide solution

37—A THEORETICAL AND PRACTICAL INVESTIGATION OF THE OPERATION OF THE LOOM

By DR. ING. E. HONEGGER

(Professor at the Federal Institute of Technology, Zürich)

CALCULATION AND MEASUREMENT OF THE POWER CONSUMPTION OF THE VARIOUS PARTS OF A LOOM

The actual process of making a fabric calls for only a very small amount of power for overcoming the friction between the threads, for bending the threads into the form required by the weave, and possibly for tensioning the threads, or certain of them. Of much greater magnitude is the mechanical energy absorbed in accelerating the shuttle, and in overcoming the friction between the various parts of the loom and which is, ultimately, completely dissipated as heat. Compared with this amount of energy, the former can, in almost all cases, be entirely neglected.

The motions of a loom can be divided into the following groups—

- (1) The rotating parts, the speed of which is approximately constant;
- (2) The slay, which swings to and fro;
- (3) The shedding mechanism (*e.g.* the dobbie);
- (4) The picking mechanism;
- (5) All the other parts - *e.g.* the ratchet wheel mechanism, safety devices, feelers, and so forth.

The distribution of the total driving power among the various motions can be determined reliably by simultaneous calculation and experimental investigation of the loom; this has been done in the work described in the following pages. The mathematical investigation was carried out by deducing the forces exerted on every part and the power involved from the speeds and accelerations of the masses. The masses and moments of inertia were either calculated from the particulars given on the drawings or by direct measurement. Adopting a similar method to that described by H. Jenny¹ the power consumption of each part of the mechanism was measured by eliminating specified motions and accurately measuring the energy supplied to each individual part.

The investigations were carried out on a Rütli automatic loom, model 415, built in 1917, having a reed space of 43 in., width of fabric 40 in., 2,960 ends of 40's cotton warp, 7 shafts of which two were always in the top position, Stäubli dobby, and fitted with Brown-Boveri individual drive. The direct measurements made gave the following power consumptions for the individual parts, at a speed of 175 r.p.m.—

<i>Loom without warp and fabric -</i>						Watts	% of Total
Two main shafts ...	...	...	...	...	100	20
Dobby and seven heald shafts ...	...	...	...	...	98	19
Slay ...	...	...	...	...	85	17
Picking motion without shuttle	...	...	...	...	77	15
Shuttle ...	...	...	...	...	110	21
<i>Additional power required with warp, weft and fabric in place</i>						42	8
<i>Total driving power when running normally</i>						512	100

The weight and the position of the centre of gravity of the slay were determined by direct measurement, and the moment of inertia was deduced from an oscillation test.

Weight of slay + $\frac{1}{2}$ crank arm	...	...	...	67.5	kg.
Mass of slay + $\frac{1}{2}$ crank arm	...	...	...	0.069	kg. cm ⁻¹ s. ²
Moment of inertia of slay about horizontal axis through centre of gravity	...	...	...	20.00	kg cms ²
Crank radius	...	...	...	7.00	cm
Length of crank arm	...	...	...	28.6	cm.
Distance between axis of rotation of slay and centre of gravity	...	...	...	69.0	cm.
Distance between axis of rotation of slay and point of application of crank arm	...	...	...	74.0	cm

During a complete revolution of the crankshaft at constant speed, the kinetic energy of the slay varies as shown in Fig. 1. The two maxima during the forward and backward movements are 550 and 538 kg. cm. The following values for the kinetic energy of the rotating parts are obtained by calculation.

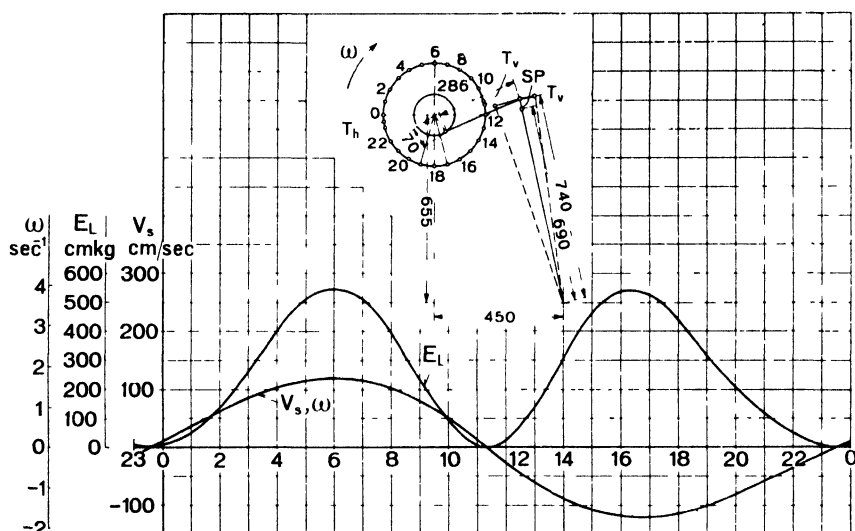


Fig. 1

Diagram of slay and crankshaft

The curves show v_r , ω , and E_f as a function of the position of the crank

T_f = front dead-centre, T_h = rear dead-centre

SP centre of gravity

v_g = speed of centre of gravity

ω = angular velocity of slave

E_1 - kinetic energy of slave

Table I

Rotating Part			Flywheel Effect kg. m ²	Revs. per min	Kinetic Energy kg. cm
Rotor of motor	...	...	0.033	950	420*
Crankshaft	...	...	2.325†	175	1000
Camshaft	...	...	2.400	87.5	260
Total	...	...	...	...	1680 kg. cm.

* Hanton² finds that the kinetic energy of the motor rotor is greater than that of all the other parts of the loom. In his case, therefore, the motor exercises in the purely mechanical sense a much greater equalising influence than in our case.

† One half of the crank arm is supposed concentrated at the crank pin, the other half is included with the batten.

VARIATION OF THE SPEED AND DRIVING TORQUE

If the empty loom is driven without dobby and picking mechanism, it requires about 185 watts, corresponding to a torque of 103 kg. cm., at 175 r.p.m. The actual torque, however, fluctuates widely due to the rise and fall in the kinetic energy of the slay. To keep the speed absolutely constant, the energy supplied would have to vary from large positive values to large negative values. If, on the other hand, the driving torque were to be kept constant, the speed would vary such that the sum of the kinetic energies of all the parts would remain invariable. The calculated degree of irregularity would be 15 per cent.* By means of a Geiger torsiograph,† the diagram reproduced in Fig. 2 was obtained, from which the degree of irregularity of the loom was ascertained to be 16 per cent.

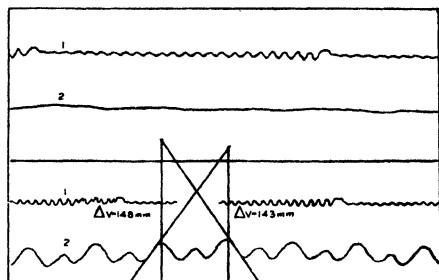


FIG. 2

FIG. 2

Loom running empty without pick and dobby

Diagram taken with Geiger instrument
Above—Slay also out of action

Fluctuation ~ 0

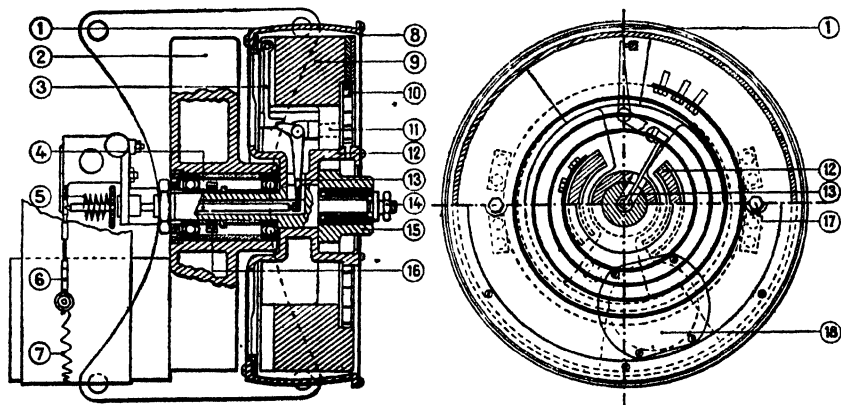
Below—With slay in operation

$$\text{Fluctuation} = \frac{148 + 143}{1725} = 0.163 = \sim 16\%$$

1—Oscillation with constant frequency

2—Curve recorded with Geiger torsiograph

* Here and throughout this article the small fluctuation of the frictional work due to the variation in the speed has been neglected.



†The Geiger torsiograph is shown in the plan and elevation here given.

The pulley 1 is driven by a special belt from the loom shaft. This pulley is connected by a spiral spring 10 to a heavy flywheel 9. The pulley, which is very light (aluminium), and the flywheel are both supported in ball bearings; there is no other connection between them than the spring above mentioned. If the pulley is driven with a speed varying periodically, the spring will transmit the mean movement to the flywheel; owing to its great inertia, the flywheel will not follow the speed variation, but will rotate at a constant speed. The spring must be suitably chosen for every test. The relative movement of the pulley to the flywheel gives a direct measure of the irregularity of rotation of the shaft controlled. This relative movement is transmitted by a system of little levers to a writing pen 6, which will draw a line on a paper moved by a constant speed. If the pulley is being driven at constant speed, the line will be straight. The inclination of the graph is proportional to the speed variation of the pulley.

The investigation was now extended to the *empty loom without dobby but with picking mechanism*. The pick is made between points 17 and 19 on the crank circle while the main shaft rotates through 30° . Since the measured mean power required by the pick is 187 watts, the power which has actually to be developed for the duration of the pick is $187 \times \frac{360^\circ}{30^\circ} = 2240 \text{ W} = 228.5 \text{ kg. m/sec.}$ corresponding to a torque of 1,245 kg. cm. Thus it would only be possible for the speed of the loom to remain constant if a sudden peak at the moment the pick was made were to be added to the torque curve previously determined (Fig. 3). The calculation of the speed at a constant

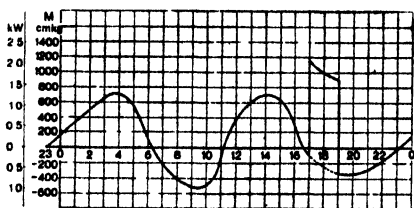


FIG. 3

Loom running empty, without dobby
Variation of the driving torque with speed
constant at 175 r.p.m.

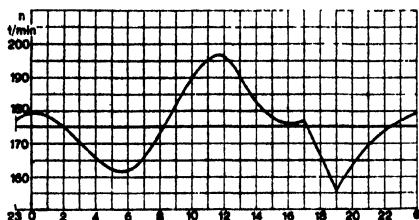


FIG. 4

Loom running empty, without dobby
Variation of crankspeed when driving
with constant torque of 207 kg. cm.

torque of 207 kg. cm., corresponding to the mean power consumption, leads to the curve reproduced in Fig. 4, which shows a maximum degree of irregularity of 23 per cent.

Actually, however, the torque developed by the motor will not be constant, as the speed of the motor will follow the fluctuations in the speed of the loom. If the motor follows the speed fluctuations shown in Fig. 4, then

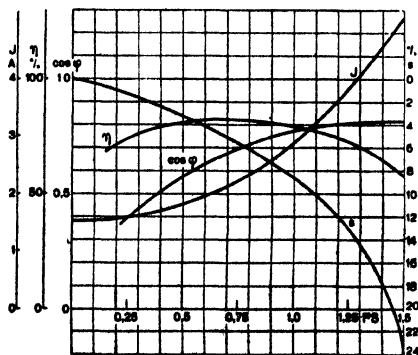


FIG. 5

Characteristics of the 3/4-h.p. motor—
Slip, efficiency, power factor, current

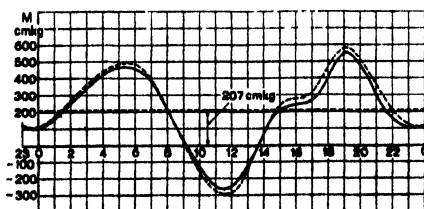


FIG. 6

Loom running empty, without dobby
Variation of the torque during one
revolution of the crankshaft
Dotted curve=first approximation
Full curve=second approximation

according to the motor characteristic, Fig. 5, the torque will vary as shown by the dotted curve in Fig. 6. If the speed is now calculated afresh with the torque thus determined, the dotted curve reproduced in Fig. 7 is obtained. A repetition of the same method, starting with the curves found, gives the full-line curves in Figs. 6 and 7, which can be considered as very close approximations. According to these the maximum degree of irregularity would be about 20 per cent. The corresponding Geiger torsigram (Fig. 8) gave a maximum degree of irregularity of 22 per cent. The discrepancy between this and the calculated value lies within the limits of accuracy of calculation and measurement. Measurements carried out later with more accurate methods led, in the same way as those with the Geiger apparatus, to practically the same results as the calculation. From the good agreement between these and later measurements and the calculated results it must be concluded that the assumptions made in the calculation are correct.

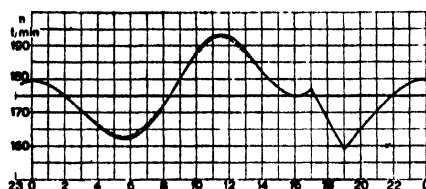


FIG. 7

Loom running empty, without dobby
Variation of the speed during one revolution of the crankshaft

Dotted curve=first approximation

Full curve=second approximation

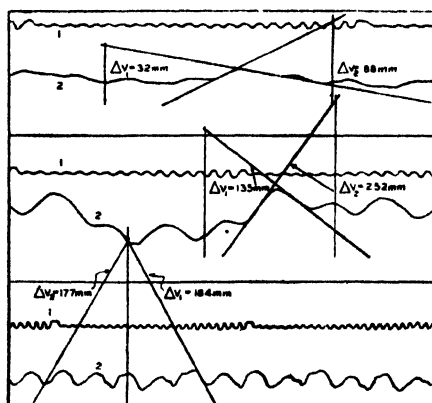


FIG. 8

Loom running empty

Above—Without slay and pick, with dobby

$$\text{Irregularity} = \frac{32 + 88}{1743} = 0.07 = 7\%$$

Middle—With pick, with slay and dobby

$$\text{Irregularity} = \frac{135 + 252}{1696} = 0.228 = 22.8\%$$

Below—Without dobby, with slay and pick

$$\text{Irregularity} = \frac{184 + 177}{1666} = 0.217 = 21.7\%$$

1—Oscillation with constant frequency

2—Curve recorded with Geiger torsigraph

In practice it is impossible to calculate the influence of the dobby on the running of the loom. From torsigrams (Fig. 8) when driving the two main shafts and the dobby, and with the slay and pick out of action, it was seen

that the dobby increases the degree of irregularity much less than the slay and pick, a fact which can be readily understood.

These measurements and calculations show that a loom, even with individual electric drive, is subject to considerable fluctuations in speed. Strictly constant speed could be attained by using a synchronous motor, which would have to be powerful enough to overcome the load peaks. It is obvious that in practice such a solution is out of the question, not only on account of the high cost but also because a synchronous motor will not start by itself. Induction motors do not suffer from this drawback, but on the other hand their speed varies with the power developed. The speed fluctuation can be limited to a certain extent by using a very powerful motor, as this can overcome the load peaks with a smaller drop in speed and because the heavier rotor has a greater speed-equalising effect.*

The reduction of the degree of irregularity by purely mechanical means in the form of heavy flywheels is out of the question as they render it difficult to start and stop the loom quickly. When driven from a line-shaft the shafts of the loom exhibit other speed fluctuations, in addition to those already mentioned, due to the unsteady running of the line-shaft. This point will be discussed later.

Even though with individual electric drive it is not possible to eliminate completely, or even to a great extent, the uneven running of the crankshaft caused by the inherent features of the loom, nevertheless it enables a very important advantage to be obtained—as long as the voltage and frequency of the supply network remain constant, the loom will perform every working cycle in exactly the same manner, and every recurring movement at the same speed and will thus ensure the desired uniformity in the fabric.

The speed variation must, nevertheless, be considered as a very undesirable feature. If it is examined closely with the help of Fig. 7, it will be seen that from the technical point of view it is as unfavourable as possible; the two maximum values of the speed coincide approximately with the forward and rear dead-centres, and the minimum values with the highest and lowest positions of the crank. From the point of view of the weaving, a slower speed at the rear dead-centre would be desirable to give more time for the pick, whilst it would be of still greater value if the beating-up could be carried out at reduced speed so that the same, or better, effect could be obtained with less force⁴. On the other hand, for the forward and backward movements of the slay a high speed would be desirable in order to save time.

The speed fluctuation which actually occurs, and which is directly opposed to the requirements of the loom, has always been a characteristic failing of the loom inherent to its design, as has already been shown. With the object of improving the operation, however, it must be endeavoured to reduce the variation (it being impossible to interchange directly the maxima and minima). As indicated in the previously-mentioned investigation⁴, a very moderate increase in the duration of beating-up can produce a noticeably favourable improvement in the woven fabric. In this way every reduction in the irregularity must have a favourable effect on the quality of the fabric, as it reduces the excess speed of 10% (according to Fig. 7) prevailing when beating-up and thus increases the duration of beating-up for

* R. H. Wilnot³ contends that with electric individual drive the degree of variation is kept down to a few per cent. On the basis of our investigations we cannot support this view.

given r.p.m. The reduction in the irregularity obtainable due to the characteristics of the motor can be seen from Figs. 4 and 7. The first diagram shows an irregularity of 23.2% with a drive with constant torque, *i.e.* with an imaginary perfectly flexible motor,* while in the second diagram the irregularity has fallen to 19.8% with a standard motor.

In addition to these speed variations, which are repeated regularly every working cycle when individual drive is used, other irregular speed variations of definitely disturbing effect occur with line-shaft drive due to belt slip and to the mutual influence of the looms driven from the same shaft. According as to whether these looms happen to be running in phase or not, the shaft will have a greater or less degree of irregularity and thus influence the operation of the looms accordingly. Fig. 9 shows some tachograms taken on various looms with line-shaft drive, while Fig. 10 shows some taken on looms with individual drive, the majority being Brown-Boveri Rüti built-in gear drives. Without paying particular attention to the absolute magnitude of the fluctuations, it is at once obvious how regular they are with individual drive, and how completely lacking they are in regularity with line-shaft drive, which confirms the deductions already made. It is unnecessary to produce further evidence to show that irregularity in the running of the loom, such as occurs with line-shaft drive, is a very definite disadvantage because the various movements are then carried out at varying speed from one cycle to the next, which can spoil the uniformity of the fabric. The absolute value of the irregularity is not necessarily much greater as compared with individual electric drive. This in itself is no criterion for the satisfactoriness of the drive.

The accurate oscillographic measurements described in the following chapter give further proof of the regularity of the speed diagram for a working cycle with individual drive.

COMPREHENSIVE MEASUREMENTS TAKEN ON THE LOOM WHEN DRIVEN BY VARIOUS TYPES OF MOTORS

Description of the Test Procedure

Now that the inherent advantages of the electric individual drive have been demonstrated, the question arises as to how this type of drive can be made most efficient. How far this question is from being solved is shown, for example, by H. Stein⁵, who places requirements on the motor in direct contradiction to previous practice.

The question is so complicated that it can only be answered reliably by experimental means. For this reason a further series of tests was carried out on the loom, involving the following kinds of drive—

- Four different motors suitable for loom driving.
- Belt drive with belt cradle.
- Belt drive with jockey pulley.
- Gear drive with friction clutch.

*Loom motors with a constant torque at various speeds cannot, however, be used, because practical operation would be impossible on account of their great flexibility in speed.

The following measurements were made—

- (i) The speed of the motor and loom and the speed variations;
- (ii) Current and power consumption of the motor, also the power factor;
- (iii) Active and reactive power from meter readings;
- (iv) Number of weft threads introduced;
- (v) Temperature of the motor.

In every case the measurements (which lasted from two to 4 hours) were only taken after the loom had been running steadily for at least four hours so that everything was well run-in. All tests were carried out under identical conditions.

The characteristics of the four motors* were determined by no-load, short-circuit and braking tests. For Motor No. 1 the speed corresponding to the stalling torque was 150 r.p.m., and for the three other motors about 600 r.p.m. A few characteristic figures for the four motors are also given in the following table—

Motor	Flywheel effect kg m ²	Normal output H.P.	Braking Data			Cos ϕ	H P max	Starting Torque	
			Volts	Amps	η %			kg m	Multiple of normal
1	0.033	0.5	250	1.50	78.5	0.725	0.80	1.21	3.06
2	0.033	0.5	250	1.45	82.5	0.72	1.15	0.92	2.45
3	0.034	0.75	250	2.25	82	0.70	1.50	1.26	2.22
4	-	0.75	250	2.22	80	0.71	1.90	1.42	2.56

A few remarks should be added about the methods of measurement used.

Speed and irregularity were determined by means of constantly excited dynamos whose voltage was recorded by oscillographs. One dynamo was coupled to the motor shaft and the other to the loom crankshaft such that they had to follow exactly the movements of these machines. The flywheel effects (weight \times diameter) of the rotors of the two dynamos were 0.028 and 0.040 kg. m². The rotor of the dynamo coupled to the motor had approximately the same moment of inertia as the rotor of the motor itself and it was thus possible for it to exercise a noticeable equalizing effect on the running of the motor, while the mass of the rotor of the second dynamo was negligible compared with the mass of the moving parts of the loom.

The oscillogram of the voltage of the tachometer dynamo is of wave form due to the influence of the commutator laminations; the mean value can, however, be interpolated easily enough and with sufficient accuracy. The tachometer dynamos were calibrated and continually checked with ordinary precision tachometers.

A contact operated from the crank-shaft made a mark on the oscillograms indicating the instant at which the pick was made. This precaution was not absolutely necessary as the drop in speed denoted the pick with sufficient accuracy. It was not, therefore, used for all the measurements.

The *power* consumed by the motor was measured accurately with power meters, but as a matter of interest was also determined by the 2-wattmeter method. This method suffers from the disadvantage that the pointers always oscillate, making the readings rather uncertain. Nevertheless, the results agreed well with the values obtained from the meter readings (maximum

*Motors 1 and 4 were specially designed for these tests and do not correspond to the standard designs.

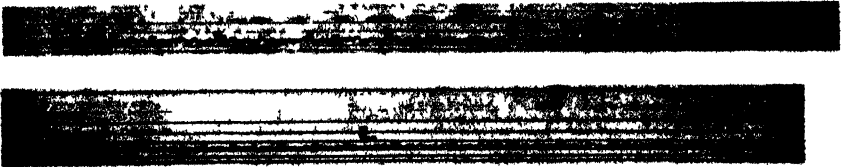
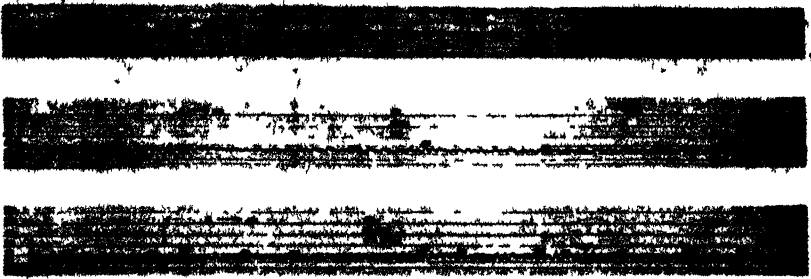


FIG 9—Tachogram of loom with lineshaft drive
In the order given—Three automatic cotton looms
One Jacquard silk loom
One silk loom with dobby
One ordinary cotton loom

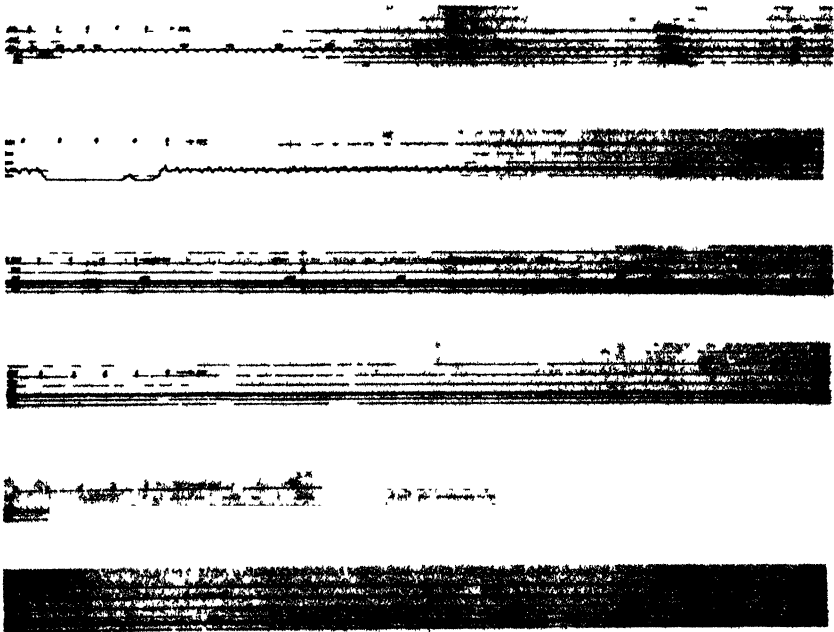


FIG 10—Tachograms of looms with individual electric drive
In the order given—One Jacquard silk loom Gear drive
One heavy woollen loom with six shuttles Gear drive
Two automatic cotton looms with Brown Boveri Ruti gear drive
One silk loom (with dobby) with Brown-Boveri Ruti drive
One woollen loom with Brown-Boveri Ruti drive

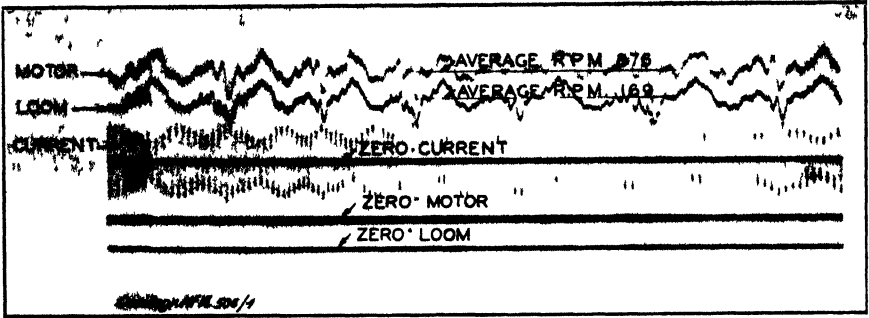
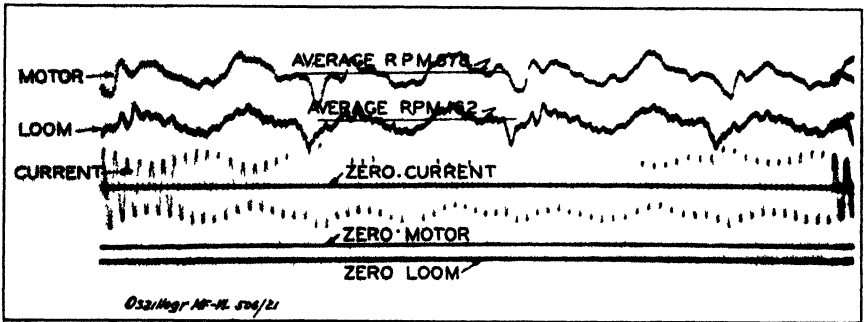


FIG 11

Motor 1—Gear drive

Oscillograms of motor and loom speeds and current



Motor 1—Belt drive with belt cradle

Oscillograms of motor and loom speeds and current

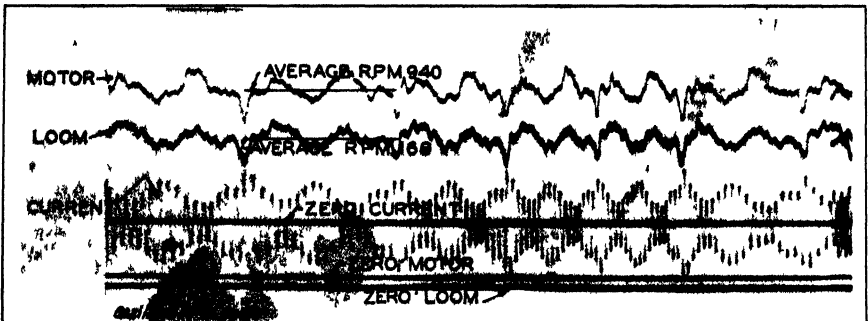


FIG 13

Motor 2—Gear drive

Oscillograms of motor and loom speeds and current

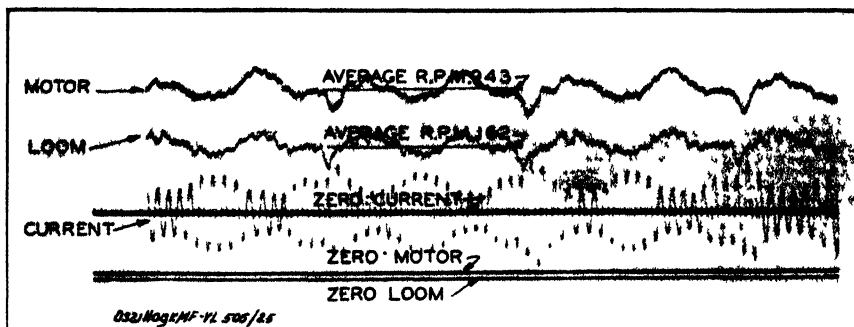


FIG. 14

Motor 2 — Belt drive with belt cradle
Oscillograms of motor and loom speeds and current

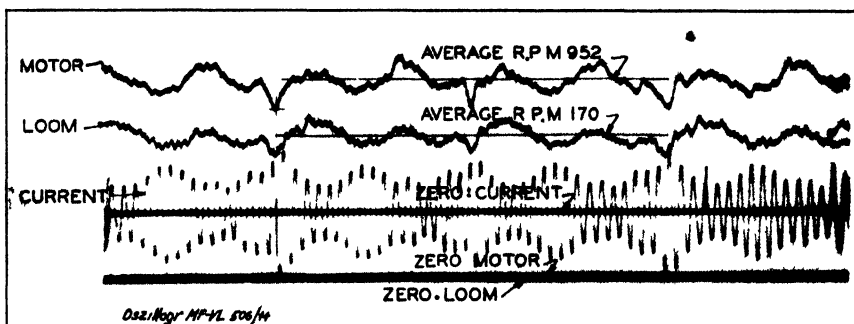


FIG. 15

Motor 3 — Gear drive
Oscillograms of motor and loom speeds, and current

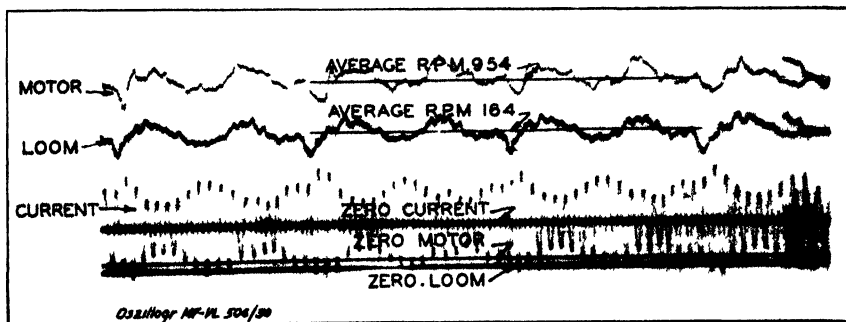


FIG. 16

Motor 3—Belt drive with belt cradle
Oscillograms of motor and loom speeds, and current

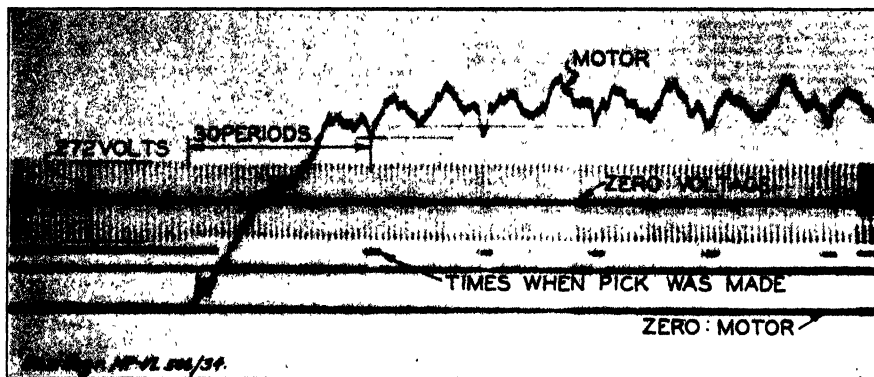


FIG. 17

Motor 1—Belt drive with jockey pulley

Oscillograms taken at starting of motor speed, voltage and times when pick was made

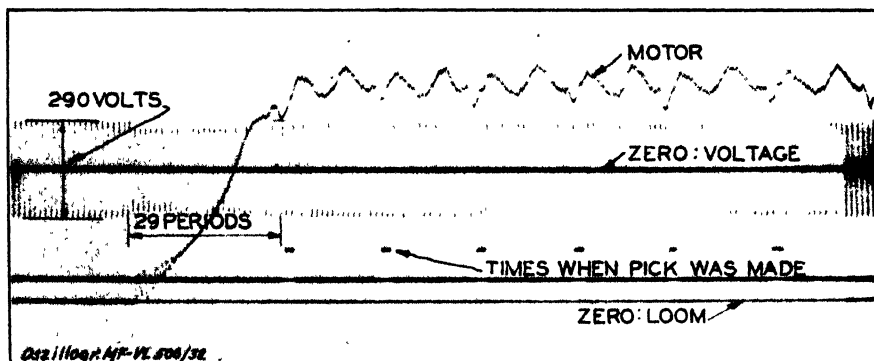


FIG. 18

Motor 2—Belt drive with jockey pulley (starting from unfavourable position of crankshaft)
Oscillograms of motor speed, voltage, and times when pick was made

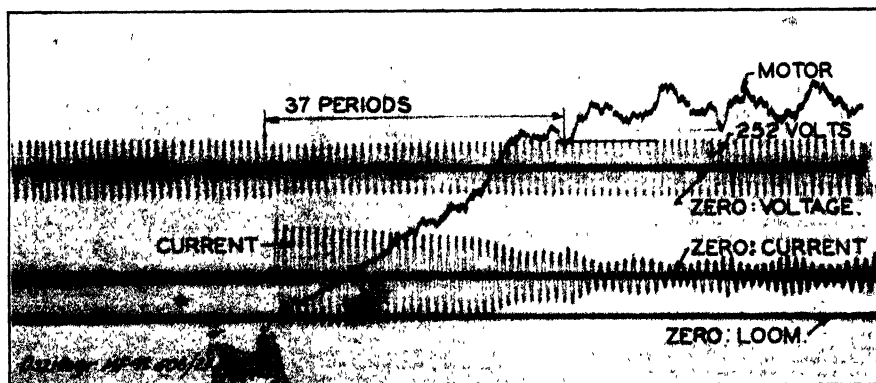


FIG. 19

Motor 2—Belt drive with belt cradle

Oscillogram at starting of motor speed, voltage, and current

Table III—Test Results

No	Motor No	H P	Z ₁ /Z ₂ (No of Teeth d ₁ /d ₂ Diameter in mm)	Average Motor R.P.M	Average Picks per minut	Amperes	Meter readings—Average for 10 revolutions of the looms		Watts for 16A picks per minute (from g)		Effici ency of Motor	Number of Picks given	Hours of con tinued Weaving no time lost	Hours of Weaving exc time lost	Total Energy used k Wh	Energy Lost in In-stru ments (watts)	Energy required by Loom (watts)	Hours required for to,000 Picks	Temperature of Air in Weaving Shed °C	Motor Casing °C
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
a	1	0.5	27 140	876	169	1.70	475	505	0.73	500	78	30,000	3	2.96	1 655	150	509	502	18.5	47
b	2	0.5	25 140	940	168	1.77	486	495	0.71	495	82	26,700	2.97	2.65	1 480	148	503	500	19	44
c	3	0.75	25 140	952	170	2.16	692	534	0.61	522	82.5	24,000	2.5	2.35	1 370	125	531	520	20	51
d	4	0.75	25 140	960	171.5	2.25	720	579	0.62	552	80	21,800	2.3	2.12	1 315	92	579	562	22	58
e	1	0.5	70 393*	878	162	1.67	465	485	0.72	521	78	37,100	4	3.82	2 04	200	481	496	20	50
f	2	0.5	65 393	943	162	1.71	482	465	0.70	500	82	29,200	3.5	3.0	1 58	175	470	482	19	44
g	3	0.75	65 393	954	164	2.1	684	507	0.59	532	82.5	26,600	2.75	2.7	1 51	138	508	517	19	49
h	1	0.5	70 393*	876	164	1.65	469	484	0.72	506	78	24,200	2.5	2.46	1 315	125	488	497	20	49.5
i	2	0.5	65 393	940	162	1.78	484	490	0.71	528	82	18,300	2	1.88	1 02	100	490	503	20	46.5
k	1	0.5	27 140	876	169	1.67	476	506	0.73	500	78	38,500	4	3.8	2 11	160	512	506	21	51.5
l	2	0.5	25 140	940	168	1.78	482	495	0.72	495	82	27,000	2.75	2.67	1 43	110	495	490	19.5	44
b ₁	2	0.5	26 140	936	173.75	1.83	493	530	0.73	495	82	—	—	—	—	—	—	—	21	47.5
b ₂	2	0.5	27 140	932	180.5	1.89	510	572	0.75	497	82	—	—	—	—	—	—	—	21	41

REMARKS—

$a-d$ } Gear drive with slipping clutch
 k and l }

$e-g$ } Belt drive with belt cradle
 h and i } Belt drive with jockey pulley

The voltage was kept constant.

The values given in Columns 5, 6, 7, 8, and 9 are mean values of ten readings

variation 2.4%), though the results obtained for the power factor were less satisfactory.

Results of the Investigations

The most important results of the measurements are given in Table III, and a number of oscillograms are reproduced in Figs. 11-16.

Running-in after period of rest—The time required daily for running-in and the corresponding increase in power consumption are at times overestimated. According to the measurements made, the increase in power required was at most 7 per cent. It diminishes very rapidly so that as a rule the driving power is down to normal in about half-an-hour or at the very latest after about 1½ hours. It should, however, be pointed out that the mill where these measurements were made during the winter was always very well heated.

Relationship between the driving power of the loom and the speed—The measurements under consideration are insufficient to enable this relationship to be determined with certainty. As far as the question was investigated (results b , b_1 and b_2) the driving power increases as the square of the speed, which agrees well with theory.

The influence of the type of drive on the power consumption was also investigated incidentally. To enable a comparison to be effected, the results of the measurements taken with the same motor but using different kinds of drives must be converted to the same speed. This was done according to the relationship given earlier. The power consumption is then—

Table IV
Power Consumption for 10,000 picks, at 168 r.p.m.

Motor	Gear drive	Belt drive with Belt Cradle	Belt drive with Jockey Pulley
1	496 Wh.	533 Wh.	520 Wh.
2	500 „	518 „	540 „
3	508 „	542 „	— „
Average	501 „	531 (525) Wh.	(531)

From these figures it follows that as regards the power consumption the gear drive is superior to the belt drive. The power consumption in the former case is less, on the average, by 6 per cent. The measurements provide no definite verdict between the belt cradle and jockey pulley. The difference between the two is, in any case, small and depends to a great extent on secondary influences (*e.g.* belt tension).

These measurements, which are admittedly limited, are favourable to the gear drive. In choosing the type of drive, however, various other factors must be taken into consideration besides the power consumption.

The irregularity of the speed (Figs. 11 to 16), measured on the loom and on the motor, is exactly the same with gear drive. The motor must thus follow implicitly the speed variations of the loom, the friction clutch not yet operating under these conditions.* With belt drive the irregularity of the

*Since the function of the slipping clutch is to protect the motor from too severe a shock when the stop rod nib falls, but otherwise should not operate, the behaviour observed fulfils expectations.

motor is somewhat smaller than that of the loom shaft. The difference between the two varies from one case to another, but is always small; once it reached 22%, but as a rule is somewhere about 5 to 10 per cent. Here as well it is impossible to discover a definite difference between the belt cradle and jockey pulley.

As will be seen by referring to the oscillograms, the irregularity in the speed of the loom varies from 23.0 to 28.4% over all the measurements taken.

The irregularity in the running of the crank-shaft was above the average when motor 1 was used. This motor was built specially for operation with an exceptionally large slip. The irregularity was greater with gear drive than with belt drive.

It is seen from the oscillograms that motor 1 never reached the synchronous speed, that is, it always ran as a motor, whereas the three other motors periodically ran as generators momentarily.†

A comparison of the calculated curve for the speed, Fig. 7, with the curves recorded by oscillograph, e.g. Figs. 12 or 15, shows immediately the close agreement between the two. The minimum value of the speed at the moment the pick is made is particularly noticeable. That this minimum point actually coincides with the pick is also substantiated by Figs. 17 and 18, in which a special contact system recorded the instant the pick was made.

The average irregularity of the loom when working as determined by direct measurement was 25%, which agrees very closely with the calculated value of 20% for the loom *without dobby*.

Table V

Fig. No.	Motor No.	H.P.	Drive	Z ₁ :Z ₂ No. of Teeth $\frac{d_1}{d_2}$ Diameters in mm.	Motor R.P.M.				Loom R.P.M.				Motor Current		
					Average	Max.	Min.	δ %	Average	Max.	Min.	δ %	Average Amp.	Max. Amp.	Min. Amp.
11	1	0.5	(a)	27/140	876	976	730	(*) 28.1	169	190	142	(*) 28.4	(†) 1.7	2.4	1.15
12	1	0.5	(b)	70/393	878	970	751	25.0	162	177	134	26.6	1.67	2.4	1.2
13	2	0.5	(a)	25/140	940	1030	805	23.9	168	184	144	23.8	1.77	3.15	0.95
14	2	0.5	(b)	65/393	943	1031	828	21.5	162	179	137	25.9	1.71	3.1	1.0
15	3	0.75	(a)	25/140	952	1035	815	23.1	170	188	149	23.0	2.15	3.7	1.5
16	3	0.75	(b)	65/393	954	1057	866	20.0	164	179	140	23.8	2.1	3.4	1.5

(a) Gear driven.

(b) Belt drive with belt cradle.

(*) δ = Variation of speed.

$$= \frac{\text{R.P.M.}_{\text{max}} - \text{R.P.M.}_{\text{min}}}{\text{R.P.M.}_{\text{average}}}$$

(†) Current measured by amperemeter.

Motor and power consumption—In order to determine the relationship between the characteristics of the motor and the power consumption, the

†W. Stiel⁶ refers to loom motors working as generators.

measured consumption in Watt-hours for a given production was converted to a given loom speed (168 r.p.m.).

Table VI—Watt-hours for 10,000 picks at 168 r.p.m.

Motor	Normal power H.P.	$\eta\%$	Gear drive	Belt drive with Belt Cradle	Belt drive with Jockey Pulley
1	0.5	78.5	496	533	520
2	0.5	82.5	500	518	540
3	0.75	82.0	508	542	—
4	0.75	80.0	539	—	—

The only strictly comparable figures are those in the same column, which are for different motors under otherwise exactly similar conditions.

The 0.5-h.p. motors require less power than the 0.75-h.p. motors, though the difference is small. The more favourable operating conditions of the smaller motors is very evident from the power factor, as the $\frac{3}{4}$ -h.p. motors were decidedly under-loaded.

The two $\frac{1}{2}$ -h.p. motors show practically no difference in the power consumption and power factor. The difference in the operating conditions of the two motors caused by the large difference in the mean slip—12% for motor 1 and 6% for motor 2—is merely evidenced by the fact that motor 1 has smaller current and load peaks. The much smaller fluctuations in the current taken by motor 1 can be clearly seen by comparing Figs. 11 and 13, and Figs. 12 and 14. The less flexible motor takes greater peak loads and runs at times as a generator, but by so doing helps to reduce the irregularity of the loom. According to the table its total power consumption is practically the same as that of the more flexible motor 1.

The running of the loom when starting up was also investigated. The oscillograms taken show the variation of the voltage, current and speed during the starting-up period. In all the tests the motor and loom were accelerated together from rest, starting with the crank in various positions. Three typical starting oscillograms are reproduced in Figs. 17, 18, and 19.

The loom must be rapidly accelerated so that the shuttle can fly right across at the first pick, and so that the first blow of the slay takes place with approximately the same force as the following ones. These conditions were fulfilled by all the drives. It was found, however, to be advantageous, even when the motor has a high starting torque, to let the loom start from the most favourable position.

Comparison of the Four Motors tested

At the risk of some slight repetition the four motors will again be compared here.

All four satisfy the conditions placed on loom motors.

The power requirements determined by the kind of loom and the fabric are most satisfactorily met by a $\frac{1}{2}$ -h.p. motor. At the same time, a comparison between a flexible motor with 12.4% mean slip and 78% mean efficiency and a non-flexible motor with 6% slip and 82% efficiency shows practically no difference in the power consumption and also no noteworthy difference in the power factor. Contrary to expectations, the particularly flexible motor did not cause a reduction in the phase displacement. This depends

largely on the mean loading.* $\frac{1}{2}$ -H.p. motors are less satisfactory from the electrical point of view due to their being run under-loaded, but have the advantage of less irregular running and also a higher production.

SUMMARY OF THE CONCLUSIONS

The theoretical and experimental investigation proves that the ordinary loom, due to its design, exhibits considerable irregularity in its running which the driving motor either follows exactly (in the case of gear drive) or very nearly (with belt drive). Practically, it is impossible to equalise completely this irregularity either by mechanical or electrical means.

It is demanded of the loom drive that it takes account of this peculiarity, that it reduces the irregularity as far as possible and that it ensures absolute consistency in the periodic speed fluctuations. A correctly designed individual electric drive fulfils these conditions.

The Brown-Boveri loom motors of standard design showed to advantage when compared with an extremely flexible test motor with a very low stalling "pull-over" torque because, with the same power consumption, they ensured a smaller degree of irregularity. Another factor which weighs against the use of a loom motor with a very weak torque-speed characteristic is the uncertainty in the resulting operating speed.

Line-shaft drive cannot be technically satisfactory because completely irregular variations in speed are inherent to it.

The investigation gave the following incidental results—

- (a) that all the motors fulfilled their duty without undue temperature rise; the most unsatisfactory in this respect was motor No. 4 which was specially built for the tests;
- (b) that the gear drive is superior to the belt drive;
- (c) that the wattless current consumption is proportionately smaller when the motors are more heavily loaded;
- (d) that when starting up, the first pick was correctly made under all conditions.

*H. Stein⁵ maintained that an exceptionally flexible motor with about 30% slip and only 59% efficiency consumes *less* power than a motor of standard design with 78% efficiency. The measurements we have made are insufficient to confirm or refute this statement, and the details given by H. Stein are so brief that they make it impossible to check the conclusions drawn. Until the publication of convincing proof, the value of a motor with such a poor efficiency must be doubted. Moreover, it is questionable how such an excessively flexible motor will work; in addition to an increase in the degree of irregularity, the resulting uncertainty in the running of the loom is also to be feared. Every small alteration in the operation of the loom—for example, in the width of the fabric or the warp tension, in the fineness of the yarn or the number of shafts—would cause an alteration in the revolutions per minute and the production of the loom due to the slightly different power requirements. Measurements taken to prove the same question in the case of a silk loom gave the following results, in direct contradiction to Stein's deduction—

Machine	Full-load efficiency %	Picks per minute	Picks per k Wh.	Picks per Wattless k Wh.	Power factor
Non-flexible motor (standard listed motor) ...	80.5	129	34,200	13,850	0.37
Flexible motor (special design) ...	74.2	129	27,800	12,000	0.39

†Mean value of 250,000 picks,

I wish to express my thanks to Messrs. Brown, Boveri & Co. Ltd., of Baden, Switzerland, at whose request and with whose help these investigations were carried out, and particularly for their permission to publish this article. I am also greatly indebted to Messrs. J. Heusser-Staub who placed looms from their mill at Wettingen at my disposal and gave every assistance in carrying out the tests.

Valuable aid was also rendered by various engineers of Messrs. Brown, Boveri & Co., namely Messrs. Emch, von Fischer, Jenny and Neukomm, as well as by my assistant at the Federal Institute of Technology, Mr. W. Stutz. I take this opportunity of thanking them all heartily.

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CORRIGENDUM

"21—THE DETERMINATION OF THE HYDROGEN-ION CONCENTRATION OF HYPOCHLORITE SOLUTIONS WITH THE GLASS ELECTRODE"

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In the above paper an error occurs on page 1189 in Table I. In line 5 for HCl read NaOH.

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